

# United States Naval Postgraduate School



## THESIS

A STUDY OF MEAN MONTHLY THERMAL  
CONDITIONS AND INFERRED CURRENTS  
IN MONTEREY BAY

by

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June 1971

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A Study of Mean Monthly Thermal  
Conditions and Inferred Currents in Monterey Bay

by

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## ABSTRACT

Temperature data, collected over the past 40 years, was compiled and averaged in the first known study of mean thermal conditions throughout the waters of Monterey Bay. The following results were obtained:

(1) The distribution of mean sea surface temperature in the Bay was obtained by calculating mean monthly values at selected grid points and drawing isotherms,

(2) Progressive warming of the upper 100m was observed to occur in a nearly linear fashion with time, resulting in a maximum temperature increase of  $1.8^{\circ}\text{C}$  over the 29 year interval from 1931 to 1960. This implies that the intensity of upwelling is also decreasing with time,

(3) Geographic variations in the rates of upwelling and downwelling, causing a relatively "warm tongue" along the Canyon axis, appeared to be a major element influencing the dynamics of the Bay, and

(4) Mean currents were inferred from the topographies of mean monthly isothermal surfaces. Limited comparisons of the inferred flow to past measured currents were very encouraging and tended to support the feasibility of such an inference in the shallow waters and irregular topography of Monterey Bay.



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## I. INTRODUCTION

Monterey Bay is a large, semi-elliptical indentation in the California coastline separated into nearly equal halves by a deep submarine canyon (Figure 1).<sup>1</sup> The outer extremity of the Bay may be defined by a line joining Point Santa Cruz to the north and Point Pinos to the south.

### A. THERMAL CONDITIONS IN MONTEREY BAY

Several studies have been conducted of thermal conditions at specific locations in Monterey Bay. The most extensive were those by Skogsberg [1936] and Bolin [1964], both spanning five year periods. Skogsberg studied the southern portion of the Bay from 1929-1933 and Bolin researched conditions at a station in the Monterey Submarine Canyon (see Appendix A). Although these studies well defined the thermal conditions for a portion of the Bay, apparently no one had investigated the Bay as a whole.

As discussed in Appendix A, the author compiled a considerable amount of temperature (and some salinity) data covering the period of time from Skogsberg's study until the present. As outlined by the author's objectives (Paragraph C), this data was utilized to study mean monthly thermal conditions throughout the Bay and to investigate the possible relationship between the thermal conditions and indicated mean currents.

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<sup>1</sup>

All figures will be found in Appendix C.



## B. CURRENTS IN MONTEREY BAY

### 1. Importance

The distribution of current in Monterey Bay is virtually unknown but there is little doubt of its great importance in determining the ecological future of the area. Pollutants, transported by the currents, are scattered freely along the beaches in the form of sewage and general rubbish. Less evident is the adverse effect on marine life created by the discharge of industrial pollutants into the Bay. Currents not only distribute "harmful" pollutants but also serve to maintain the chemical and thermal balance necessary to support marine life.

### 2. Why Little is Known Concerning Distribution of Bay Currents

The well established currents of the open oceans are relatively strong and unchanging with time (e.g., the Gulf Stream and the offshore California Current) and hence, their general movements are fairly well understood. Monterey Bay, being enclosed on three sides, presents a different situation. The Bay currents are weak and variable and their mean flow is almost completely disguised by the effects of local winds, tides, topography, and seasonal changes in the offshore currents.

Past current studies in the Bay have been of a limited nature, both in time and in geographical coverage. They have contributed towards an understanding of "short term" currents (such as those resulting from the tides) but too few observations have been made to be of much use in



describing the mean flow. In time, and with many additional current observations, a study of the combined effects could prove to be of great value.

### 3. The Feasibility of Approximating Mean Currents by the Geostrophic Approach

Indirect approximations of current using the geostrophic theory may be divided into two categories: (1) the classical use of the geostrophic method, and (2) approximations derived from the classical method.

#### a. The Classical Geostrophic Method

Basically, flow obtained by classical application of the geostrophic method is that which results from the balancing of the Coriolis force and the pressure force between two points on a surface of variable elevation. (Neumann and Pierson [1966] discuss the theory in their book entitled, Principles of Physical Oceanography). Computed elevation of the sea surface at a given location in the ocean is represented by a term called the "dynamic height," a relative parameter based on the density of sea water at the location and referred to an assumed level-of-no-motion. A high value of density (usually colder water) yields a lower dynamic height and conversely. By geostrophic theory, the circulation in the Northern Hemisphere is counterclockwise about locations of lower dynamic height (depressed surfaces) and clockwise about locations of higher dynamic heights (elevated surfaces). The level-of-no-motion is the depth of water (as best can be ascertained) where



absolute current velocity equals zero and this rarely occurs at depths less than 150m.

Accurate representation of the mean current based on the classical geostrophic method thus requires two prerequisites; (1) a knowledge of mean temperature and salinity (to obtain mean density) of the water column at several well spaced locations in the area of interest, and (2) a level-of-no-motion everywhere shallower than the depth of the bottom (otherwise, there is no reference except the bottom itself from which to compute true velocity). Finally, of course, wind driven and tidal currents are neglected in computing means.

b. Approximations Derived from the Classical Method

Several approximations to the classical approach have been used in relatively deep waters with considerable success. Barker and Denham [1970] used the classical method to plot geopotential topographies (surfaces of equal dynamic height) for various levels-of-no-motion off the northeast coast of New Zealand. The close correlation between the shapes of the topographies suggested that broad current patterns could be approximated without using an accurate level-of-no-motion. Duncan and Nell [1969] demonstrated that isopycnal (equal density) surfaces were closely related to current patterns in their study off the Cape Coast. Drift cards were employed to measure general current trends and were found to follow the isopycnal contours as predicted by geostrophic theory for





the Southern Hemisphere. Leipper [1970] demonstrated that temperature data alone could be used to approximate current in the Gulf of Mexico. Monthly topographies of the 22°C isothermal surface were constructed by him from data collected on various cruises during the period 1965-1966. The current was found to closely follow the contours, moving in a direction placing colder waters to the left of the flow. These results were verified by geostrophic flows computed at various locations in the Gulf. This approach is based on the assumption that temperature changes are directly proportional to density changes throughout the water column, and thus isothermal surfaces may be considered in place of isopycnal surfaces.

Application of any of the above approximations to the shallow waters and irregular topography of Monterey Bay would be a considerable extension of usual practice. However, the theory of geostrophic flow does not depend on the depth of water, therefore, geostrophic methods might be useful in indicating broad current patterns in the shallow waters of the Bay. Considerable temperature data was compiled for Monterey Bay in this study (see Appendix A). The author used this data to investigate the feasibility of relating mean currents to mean isothermal surfaces in a manner similar to that of Leipper.

### C. OBJECTIVES

The objectives of this study are to:



1. Compile temperature and salinity data from previous oceanographic studies conducted in Monterey Bay,

2. Conduct a study of the distribution of mean monthly temperature in Monterey Bay and construct charts of the mean monthly distribution of sea surface temperature,

3. Investigate the feasibility of inferring mean currents from the topographies of mean isothermal surfaces, and

4. Prepare a computer program for the continuing storage and retrieval of oceanographic data collected in Monterey Bay.

#### D. ORGANIZING AND USING THE DATA

The IBM 360 computer at the Postgraduate School was used to compile the temperature data and to compute monthly averages (as discussed in Appendix B). A grid system, dividing the Bay into 19 blocks, 4mi by 4mi in dimensions, was used to segregate the temperature data (Figure 1). The author's initial grid system covered a larger area (Figure 2) containing 39 blocks, but only the numbered blocks held significant data. The mean temperature of a given block, based on the averaging of all temperatures compiled for that block, was assumed to be effectively located at its center.

The temperature data was compiled over the 40 year interval from 1929 through 1968. Temperatures collected by all reliable methods were combined in the averaging process (although the computer program did allow for data to be retrieved by type, i.e., Nansen, XBT, BT).



The risks inherent in the "lumping" together of all types of temperature data spanning a 40 year interval and further reducing data from 4mi by 4mi blocks to represent points in their centers were fully realized. This lumping was essential due to the erratic distribution of data within the Bay and also because no reasonably short time span held enough data to support this study. The errors introduced by the above procedures are discussed in Chapter II.



## II. VALIDITY OF THE COMPUTED MEAN MONTHLY TEMPERATURES (AND DENSITIES)

A discussion of the questions raised in the Introduction involving the method of computing mean monthly temperatures is considered necessary before an appraisal of the results (Chapters III and IV) can be made.

### A. TIME RANGE OF DATA

Data from three separate time intervals within the previously mentioned 40 year time span was averaged and compared to determine the degree of consistency of thermal conditions relative to the progression of time. Three Bay studies (as referenced in Appendix A) were used: (1) Skogsberg (1929-1933), (2) Bolin (1951-1955), and (3) CalCOFI surveys (1954-1967).<sup>2</sup> The time intervals between midpoints (mean years) of the studies were 22 years from Skogsberg to Bolin and 7 years from Bolin to CalCOFI, with a total time interval of 29 years (1931 to 1960).

The annual thermal cycles of the three periods (Figures 4-6) were generally similar in shape with upwelling noticeable from the surface to 500m (as characterized by the humps in the isotherms during the months of April through June). A consistent feature over the 29 year interval was the apparent weakening in intensity of upwelling

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<sup>2</sup> The oceanographic stations used in these studies are shown in Figure 3. Skogsberg's station is denoted by "C", Bolin's by "B" and CalCOFI by a square numbered "3". It is noted that the three stations are contained within a radius of two mi.





with time. The 9°C isotherms from all three studies are plotted in Figure 4 to demonstrate the effect. It was observed that the depths of the 9°C isotherms were relatively close together during the winter months. During the remainder of the year (especially noticeable in May) the 9°C isotherms were observed to deviate from one another. The deviation followed a consistent pattern with the 9°C isotherm of the earliest study (Skogsberg in 1931) at the shallowest depth and the 9°C isotherms of the later two studies at greater depths as time progressed. This "flattening out" of the 9°C isotherm with time could indicate a weakening in intensity of upwelling.

A general warming with time was also observed to occur throughout the waters of the Bay. Figure 6A depicts the temperature increase ( $\Delta T$ ) observed to occur over the period from 1931 (Skogsberg's mean) to 1960 (CalCOFI's mean) at selected depths throughout the year. The curves represent the variation of  $\Delta T$  for each month and for depths from the surface to 500m. Figure 6A shows that the maximum temperature increase occurred at depths from the surface to 100m and during the period from October to December. At depths from 200-500m,  $\Delta T$  cycled between positive and negative values throughout the year; however,  $\Delta T$  was always positive (temperature increase) in the months of May, June, September, and October.

The consistently positive values of  $\Delta T$  in May and June for depths from the surface to 500m might be another indication that upwelling was decreasing in intensity (with time)



throughout this region, since the warming in May and June would also indicate a flattening out of the isotherms. The reasons for the maximum temperature increase during the months of October to December are unknown. It could be related to changes in the "Oceanic Period," or possibly, to changes in the transition period between the influence of the California and Davidson current systems.

In summary, the general warming of the water column with time was observed to be consistent in the upper 100m (by the similarity in the shape of the  $\Delta T$  curves in Figure 6A at these depths). At depths below 200m, the consistency was not as good (as observed by the  $\Delta T$  curves cycling between positive and negative values); however, the total range of  $\Delta T$  was only  $0.5^{\circ}\text{C}$  in the deeper waters.

The maximum temperature increase over the 29 year interval was  $1.8^{\circ}\text{C}$  (the 50m curve in November from Figure 6A) resulting in about 1/15th of a degree C increase per year. This small annual temperature change, along with the general similarity of the curves (as observed in Figures 4-6) was considered to represent consistent behaviour with time. It was concluded that the author's method of averaging temperature values was justified. This provided averages that were representative of the overall period.

## B. POSITIONING OF STATIONS

The computer grid system was based on the assumption that all temperature values found in a given block were located at its center. The grid system was initially positioned



so as to minimize the distance of known oceanographic stations from grid centers. The maximum deviation from such centers was 1.6 mi. Data was assumed to be scattered randomly around the centers of the blocks in the grid system.

### C. USE OF THREE DIFFERENT DATA COLLECTION SYSTEMS

The data was collected by Nansen, BT, and XBT devices. Several papers have been written concerning system errors peculiar to each. The magnitude of the errors in the BT's and XBT's are apparently undeterminable.

To investigate the significance of possible system errors, the standard deviations ( $\sigma$ ) of temperature (and density) values were included in the computer output.  $(\bar{X} \pm \sigma)$  represented the interval containing 67% of all values averaged for a given mean ( $\bar{X}$ ).

Standard deviations of mean monthly sea surface temperature versus time (by months) were plotted for selected blocks. Figure 7 (Block 13) represented the worst condition found. The larger standard deviation in July was not representative; the consistent features of all graphs were: (1) minimum values of standard deviation for the month of January, and (2) the relatively small variation of the values throughout the year.

Plots of standard deviation versus depth (Figure 8) were also consistent. Values of standard deviation halved within 30-40m of the surface, reached values of  $0.5^{\circ}\text{C}$  anywhere from 50-275m and then linearly decreased to minimum values of



0.1-0.2°C in deeper waters. The decrease of standard deviation with increasing depth of water and its practically invariable value (0.1-0.2°C) below 800m, where the data was exclusively from Nansen casts, indicated that seasonal changes were mainly responsible for variations in mean temperatures. System errors were thus neglected.

#### D. GEOGRAPHIC DISTRIBUTION OF DATA

The 3000 oceanographic stations used in this study (25,100 temperatures) were erratically distributed throughout the blocks in the computer grid system (Figure 2). Blocks 1-6, 13, 20, and 21S contained the major portion of the data (10-85 surface temperatures per block per month) and thus were given major consideration in the analysis. The remainder of the blocks contained random amounts of data, except for Blocks 17 and 19 which generally contained 3-6 values per month each.

Clearly, the blocks containing relatively few temperatures (less than 10 per month) would yield less reliable averages than blocks with many values. Choosing a minimum number of temperature values to achieve relatively accurate mean monthly temperatures was based on a study of continuity between weak blocks (with less than 10 temperatures per month at a given depth) and strong blocks (more than 10 temperatures).

Graphs of annual mean temperature cycles, mean monthly temperature sections, and standard deviation versus time and depth were drawn for weak Blocks 8, 17, and 19 and for strong Blocks 1-6 and 13. The annual mean temperature cycles of the







weak blocks compared closely to those of the strong blocks. This comparison was well represented by Block 19 (Figure 9) and Block 3 (Figure 10).

Further continuity in data between weak and strong blocks was demonstrated by Figure 11, showing the thermal structures of two vertical sections (see Figure 12 for location of sections), one oriented north to south connecting Blocks 1, 2, 17, and 5 (S-1) and the other oriented along the Monterey Submarine Canyon axis (S-2) connecting Blocks 13, 3, 17, and 19. The isotherms were smooth and continuous in the upper and lower waters for both sections throughout the year. In depths from 50-100m, the isotherms were smooth and continuous along section S-2. Along section S-1 the isotherms were occasionally depressed at Block 17. The depression of isotherms at Block 17 in section S-1 and lack of depression for the same block in section S-2 will be shown to be consistent in Chapter III, paragraph B.

Finally, the standard deviations of mean monthly temperatures versus time and depth were comparable for all blocks, weak or strong (Figure 7 and 8 were representative).

The continuity exhibited in the vertical sections between adjacent weak and strong blocks (and within the blocks as time progressed) supported the limited use made of the weak blocks for constructing mean monthly isothermal surfaces in Chapters III and IV. As the isothermal surfaces were prepared, the weak blocks demonstrated further consistency of data, especially Blocks 8, 17, and 19. Examples of this are noted in Chapter IV.



### III. THERMAL CONDITIONS

#### A. THE ANNUAL THERMAL CYCLE IN MONTEREY BAY

The "3-phase" annual thermal cycle occurring at specific locations in Monterey Bay has been described by Skogsberg [1936], Bolin [1964] and others. The following discussion considers the variation in mean thermal conditions relative to various geographic locations throughout the Bay, a subject apparently not previously dealt with.

Figure 12 depicts three geographic regions in the Bay that the author will refer to in this Chapter. The choice of the 50 fathom curve as a dividing line was arbitrary, but gave the desired sectioning.

##### 1. The Canyon Region

Since Bolin described the thermal conditions for the Canyon region a detailed account will not be repeated here; however, a brief description of the "phases" will be necessary for later comparisons.

##### a. The "Upwelling Period"

Commonly considered to span from mid-January to September, the Upwelling Period is characterized by the rising of the deep, colder waters. As found in this study (Figure 10), the cold waters began their upward movement in mid-January from depths as great as 700m (however, the movements were minimal below 300m). The maximum rate of rise occurred between February and March and the peak was found in April or May when the 11°C water nearly reached the



surface. Although upwelling reached its peak later at greater depths, none was observed after July.

The descent (downwelling) of the cold waters generally commenced in June and was apparent until late November at greater depths.

b. The "Oceanic Period"

This period is commonly considered to occur during September and October and is well defined by the sharp vertical temperature gradients at depths from the surface to about 100m.

c. The "Davidson Current Period"

In November the south-moving California Current is displaced by the north-moving Davidson Current along the coast. The influx of warmer waters into the Bay results in a weakening of the vertical temperature gradients and a resulting well-mixed layer of water from the surface to about 50m. The northerly flow continues until mid-January when the California Current again predominates and the "3-phase" annual cycle commences again.

2. The Regions of the Shallows (see Figure 12)

The annual thermal cycle in the Shallows was similar to that in the Canyon Region with two noteworthy exceptions:

First, the very shallow regions at the extreme northern and southern ends of the Bay possessed unique annual thermal cycles at depths from the surface to 10m. Referring to Figure 13, the annual cycle of the surface temperature in the Canyon (Block 3) showed a clear decrease



in temperature from January until early May and then a steady increase until late September (this was typical for all the deep water areas). The annual cycles of surface temperature for the very shallow waters (Blocks 1 and 5) showed no similar decrease in late winter but rather a steady increase from mid-January until late September (Figures 13 and 14). This steady temperature increase, unique for the shallow water regions (less than 75m), was probably due to greater heating of the water column from bottom reflection and the insolation of nearby land masses. This greater heating of the shallow areas is clearly shown in the distribution of mean monthly sea surface temperatures as will be discussed in paragraph E (Figures 19-30). The relatively deep regions of the Shallows areas (Blocks 2 and 4) exhibited a very slight amount of cooling from January until May, but not nearly as much as did the canyon Region (see Figures 15 and 16). The second exception is discussed below.

#### B. THE VARIATIONS IN INTENSITY OF UPWELLING

In studying the various graphs constructed for the analysis of thermal conditions, the author came upon a feature which could be an important element in the dynamics of the Bay in general. Figure 17 is introduced to show the months of the maximum rates of upwelling and downwelling during the year. Inspection of the annual cycle in Block 3 shows maximum rates of upwelling from February to March, and





maximum rates of downwelling (or heating) from July to August (note the slopes of the 10°C and 11°C isotherms).

Vertical temperature section S-1 (see Figure 12) shows a strange dipping of the isotherms at Block 17 for all of the above mentioned months (Figure 18 is representative). Block 17 was a weak block (less than 10 temperatures per month) and thus the dipping was suspected. To attempt to verify the dipping of isotherms in the Canyon, two additional sections were constructed (see Figure 12 for locations), both running across the Canyon axis (as did section S-1). Section S-3 connected Blocks 2, 3, and 4, and section S-4 connected Blocks 2, 3, and 6 (emphasis is placed on the fact that sections S-3 and S-4 contained only strong blocks with greater than 20 temperatures per month each).<sup>3</sup> The results are clearly illustrated in Figure 18 which shows marked dipping of the isotherms across the Canyon axis in all sections. This results in a relatively warm tongue along the Canyon axis for the months of maximum rates of upwelling and downwelling.

The dipping of the isotherms across the Canyon axis could have been caused by the up-slope entry of the cold upwelling waters into the regions of the Shallows. During February and March, when upwelling rates are highest, the cold waters are ascending from depths down to 300m. As the

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<sup>3</sup>

Table V lists the number of temperatures compiled for the various blocks of the computer grid system.



cold, dense water spreads to the Canyon walls, its horizontal movement is interrupted, and thus it is accelerated up the walls and into the shallower adjacent regions. Conversely, in July and August, when downwelling rates are highest, the cold waters are descending from the near-surface regions. Their rates of descent are accelerated into the Canyon since the deepening topography offers no resistance to their sinking. The transition period (from April to June) between upwelling and downwelling showed no dipping of isotherms across the Canyon.

No dipping of isotherms was observed along the Canyon axis. This would be as expected since the depth of water along the axis (section S-2) was everywhere deeper than 300m thus affording no bottom influence upon the cold upwelling waters.

The annual mean temperature cycles of the relatively deep regions (Figure 16) and the very shallow regions (Figure 14) of the Shallows further demonstrated the up-slope surge idea. During the months of highest up/downwelling rates, Blocks 2 and 4 (adjacent to the Canyon) exhibited somewhat stronger upwelling (greater slopes of the 10°C and 11°C isotherms) than did Blocks 1 and 5 which were at the extreme northern and southern ends of the Bay. It thus appeared that the cold up-surfing waters might have lost some of their momentum by the time they reached the very shallow regions of Blocks 1 and 5.



C. COMPARISON OF THE ANNUAL THERMAL CYCLE IN THE BAY  
TO THAT OF AN OFFSHORE LOCATION

Block 20, located 22 mi west-southwest of the Bay (Figure 2) was compared to Block 3 in the Canyon. Figure 17 demonstrated two broad differences between the thermal conditions of the two locations.

1. Mixing in the Upper Layers

The offshore station exhibited generally warmer surface waters throughout the year and better mixing of the upper waters (0-50m) from January to April. At onset of the "Oceanic Period" in September, the offshore and Bay stations both exhibited maximum vertical temperature gradients.

At the close of the "Oceanic Period" in November, the Bay station exhibited somewhat better mixing than did the offshore station, maintaining its more uniform surface waters until January. The weakening of the vertical temperature gradients in the Bay (as described by Bolin) was assumed to be the result of the influx of warm waters brought into the Bay by the north-flowing Davidson Current (during the period of November through January). The more uniform mixing of the Bay waters might have been due to a greater influence by the Davidson Current nearshore.

2. Upwelling

Upwelling is considered to result from the northerly winds deflecting the surface waters to the right and away from the coast, allowing the deeper cold waters to rise. The intensity of upwelling should then decrease as the distance



to the coast increases. Figure 17 demonstrated that this was indeed the case, Block 20 showing less intense upwelling than Block 3.

#### D. PROGRESSIVE WARMING

Chapter II, paragraph A, contains a discussion of the progressive warming found for the entire water column in the Bay over the 29 year interval from 1931 to 1960. It should be noted that Bolin [1964] found an opposite indication of progressive cooling from 1951-1955. He investigated the "previous and subsequent" sea surface temperatures taken at selected locations along the west coast of North America and found that the years of his study were all relatively cool and that 1955 had the minimum temperature in a "long-term trend." In Chapter II, evidence was presented indicating continual progressive warming over the 29 year interval noted above. It thus appears that the cooling observed by Bolin was a short-term cycle.

#### E. THE DISTRIBUTION OF MEAN MONTHLY SEA SURFACE TEMPERATURE IN MONTEREY BAY

Figures 19-30 depict the distribution of mean monthly sea surface temperature in Monterey Bay.

##### 1. Description of Figures

The dots on each figure (representing the centers of their respective blocks) served as the points from which isotherms were drawn. The values of mean monthly temperature are directly below the points. Table I lists the total number of temperature measurements per block per month (at





TABLE I. The Range in the Total Number of Temperatures  
Averaged to Compute the Means for Blocks in  
the Bay

BLOCK NO.	DEPTH (m)	RANGE OF TOTAL TEMPERATURES PER MONTH AT 0 & 50m											
		J	F	M	A	M	J	J	A	S	O	N	D
1	0	65	62	62	65	64	61	67	65	60	70	72	70
	50	0	0	0	0	0	1	0	0	0	0	1	0
2	0	62	64	64	67	64	61	68	65	61	68	70	67
	50	6	9	6	9	8	10	10	9	8	11	9	9
3	0	79	79	79	84	77	69	84	81	77	83	94	85
	50	23	25	20	24	21	18	23	21	24	22	32	26
4	0	76	80	68	76	72	72	86	78	72	83	87	80
	50	20	25	10	13	15	20	23	16	18	23	28	21
5	0	65	66	67	67	63	60	68	64	63	70	69	68
	50	----- DEPTH OF WATER LESS THAN 50m -----											
6	0	69	60	64	70	66	62	69	65	60	67	70	68
	50	9	6	6	8	6	7	11	7	6	9	8	7
7	0	0	0	0	0	0	1	0	0	3	2	1	0
	50	0	0	0	0	0	0	0	0	2	1	1	0
8	0	11	5	0	10	8	9	6	5	2	7	8	5
	50	11	5	0	9	8	7	5	5	2	7	8	5
13	0	22	24	20	23	27	23	22	21	18	25	21	21
	50	22	24	20	23	27	23	22	21	18	25	21	21
16	0	2	0	0	2	0	4	1	0	1	0	1	1
	50	----- DEPTH OF WATER LESS THAN 50m -----											
17	0	4	18	4	4	3	3	5	3	6	5	6	4
	50	4	18	4	4	3	3	5	3	6	5	6	4
19	0	4	4	4	3	4	5	4	3	4	5	6	4
	50	4	4	4	3	4	3	4	3	4	5	6	4
20	0	10	3	2	12	8	13	9	5	5	6	5	3
	50	10	3	2	12	8	13	9	5	5	6	5	3
		J	F	M	A	M	J	J	A	S	O	N	D

Note 1: Blocks 9-11, 14, and 18 seldom contained data.

Note 2: Block 20 (see Figure 3) is located 22 mi offshore.



the surface and 50m) that were used to compute the mean temperatures. Mean temperatures are not listed (or used) in the figures if less than four values were available for averaging. Dashed lines represent probable extensions of the isotherms.

The circle in the upper right hand corner of each figure displays the local mean wind condition (taken from the U. S. Naval Oceanographic Office "Pilot Charts," series H.O. 1401) and the mean offshore currents (taken from the U. S. Naval Oceanographic Office Publication H.O. 570). The local mean winds are shown as a series of arrows (fine lines) that fly with the winds. The lengths of the arrows represent the percentages of the month that winds were from the directions shown (the percentage shown for the longest arrow serves as a reference). The number of tails on a given arrow defines the wind force by the Beaufort Scale, as shown below:

<u>Number of Tails</u>	<u>Mean Wind Force (kt)</u>
0	0
1	1-3
2	4-6
3	7-10
4	11-16
5	17-21
6	22-27
7	28-33

The mean offshore current is displayed by an arrow (bold line) extending the diameter of the circle. Mean current



direction is with the arrow and its speed (miles per day) is displayed inside the inner circle.

The upper left hand corner of each figure shows the mean sea surface temperature at a location 15 mi offshore. This data was taken from Naval Oceanographic Office Special Publication, SP-123, and represented mean monthly values based on ship's injection temperatures collected over the past 100 years.

## 2. Discussion

### a. The Annual Cycle of Mean Sea Surface Temperature

The following two factors appear to influence the distribution of mean sea surface temperature.

#### (1) Upwelling

The coldest waters in the Bay occur during the period from February to May (with April being the coldest month of the year) coinciding with the upwelling period. Figures 20-22 show the intrusion of the colder waters from seaward. It appears that the main intrusion broadly occurs along the axis of the Submarine Canyon (note the 11°C and 12°C isotherms in Figure 22).

#### (2) The Variation in Mean Air Temperature

According to data contained in the U. S. Naval Oceanographic Office Pilot Chart series, the mean air temperature is at a minimum in January, rises to an annual maximum in September to October, and then falls to a minimum again in January.

The relation of mean sea surface to mean air temperatures is demonstrated by following the monthly position of the 13°C isotherm. In January and February its



absence implies generally colder waters. In March it was seen to intrude into the Bay near the Moss Landing area. In April, the 13°C isotherm appears to be pushed aside by the intrusion of the colder waters (Figure 22). During the period from May to October, the 13°C isotherm was observed to move steadily seaward as the waters in the Bay continued to warm. Although the positions of the 13°C isotherms are nearly identical in September and October, the overall thermal distribution shows September to be the warmest month of the year (Figure 27). From October until January, the 13°C isotherm was observed to move steadily towards shore indicating the broad cooling of the surface waters.

#### b. Horizontal Sea Surface Temperature Gradients

Horizontal temperature gradients are weakest during the period from November through January with nearly uniform temperature throughout the Bay (less than 0.5°C change) occurring in January. The uniform temperatures characterizing this period are probably due to the influx into the Bay of warmer waters from the north-flowing Davidson Current (prevailing during the above period). In February, the temperature gradients are stronger and continue to increase in strength until reaching their annual maximum in July. The mean offshore sea surface temperature of 13.9°C in July indicates that strong gradients are also set up offshore as well as in the Bay. Steady weakening of temperature gradients occur from August until January, completing the annual cycle.





It will be recalled that maximum vertical temperature gradients occur in the surface layers during the Oceanic Period from September to October (see Figure 10). Bolin related the occurrence of maximum vertical gradients to the relatively windless (and also the minimum velocity of the California Current) conditions prevalent during this period. The occurrence of the maximum horizontal sea surface temperature gradients in July (2-3 months earlier than the maximum vertical gradients) might be related to the greater velocity of the south-flowing California Current. The cooler waters carried into the Bay by this current move at twice the velocity in July as compared with September to October (3.6 versus 1.7 mi/day). Hence, the outer Bay regions are colder while the inner or nearshore regions continue to warm from atmospheric heating.

The mean sea surface temperatures in the northern and southern areas of the Bay are consistently warmer than those in the center area for all months except November through January (when generally uniform temperatures prevail). The northern area exhibited consistently higher temperatures than did the southern area throughout this period. The warm spot in the northern region is probably due to the shallower depths of water there (see Figure 12) thus permitting greater insolation and reflective heating of the waters as earlier mentioned. Also, the shallower northern region is somewhat isolated from the effects of upwelling and thus does not undergo mixing with the deeper and colder waters.



### 3. Summary

Inspection of the mean isothermal surfaces portrayed in Figures 19-30 reveal several blank spots in the data field, especially in the northeastern section of the Bay. It would be of considerable benefit to conduct a further search for data within these blank spots (Blocks 16, 18, and the non-numbered block shown crossed out in Figure 1) thus providing a more complete picture of the sea surface temperature distribution.



#### IV. USE OF ISOTHERMAL SURFACES AS INDICATORS OF MEAN CURRENT

If mean flow can be approximated in Monterey Bay using mean isothermal surfaces, then the topographies of these surfaces must be associated with all dynamic forces acting to establish mean flow. Some of the factors involved are as follows:

##### A. POSSIBLE GENERATING FORCES

###### 1. Offshore Currents

The offshore currents are considered by some to be the major driving forces behind the generation of Bay currents. Some theorists believe that a northerly flow adjacent to the Bay will establish a clockwise gyre within it, and conversely for a southerly flow. This theory was presented recently by Garcia [1971] using a mathematical model of the Bay.

###### a. The California Current

Transgressing a large clockwise circle in the Northern Hemisphere, the California Current makes its way south along the coast year-round. The southern flow of its outer boundaries is felt at the seaward edge of the Bay from mid-February until early November, with mean velocities ranging from 1.0 to 6.7 mi/day (see Chapter III, paragraph E.1).

###### b. The Davidson Current

Prevailing from November to early February, the Davidson Current flows north adjacent to the coast, bringing relatively warmer waters into the Bay (see Figure 31).



## 2. Winds

Long acting and relatively steady winds will generate related current patterns wherever and whenever such wind systems exist.

## 3. Tides

Tidal currents are active in Monterey Bay but are not considered in this study since they are very nearly (if not entirely) averaged out in taking monthly means.

## 4. Upwelling

Upwelling has been studied as thoroughly as any oceanographic feature, but almost all studies considered only its vertical aspects. As discussed in Chapter III, paragraph B, the author found that the horizontal differences in upwelling in the vicinity of the Submarine Canyon were apparently a contributing factor in the resulting shapes of the mean isothermal surfaces (possibly a major factor during the months of maximum rates of up/downwelling). The possible influence of up/downwelling upon mean indicated currents is discussed in paragraph D of this chapter.

### B. VERIFYING THE CORRELATION BETWEEN ISOTHERMAL AND ISO-PYCNAI SURFACES

To employ an approach similar to that used by Leipper [1970] in the Gulf of Mexico (discussed in the Introduction), it was first necessary to show that changes in mean density were directly proportional to changes in mean temperature throughout the water column in the Bay. There was not enough data available on mean density to allow the construction of vertical density sections, therefore, annual





cycles of mean density and temperature (for several blocks) were compared. The results showed that mean density and temperature were closely related throughout the Bay and at all depths considered except in the region above 10m where the correlation was not quite as good. The below listed comparisons demonstrated the results:

- (1) Figure 32 (mean density structure, Blocks 1 and 5) to Figure 14 (mean temperature structure, Blocks 1 and 5),
- (2) Figure 32 (mean density structure, Block 20) to Figure 17 (mean temperature structure, Block 20),
- (3) Figure 33 (mean temperature structure with mean density structure (dashed lines) superimposed, Block 13).

The relatively small total change in mean density throughout the water column was not unexpected. Previously measured currents in the Bay were generally on the order of 0.25 to 0.5 kt, and rarely (if ever) exceeded 1 kt. Therefore, the small changes in density (assuming isopycnal surfaces are related to indicated mean current) would imply small values of mean current. This appears to be the case.

#### C. PORTRAYAL OF THE ISOTHERMAL SURFACES

The foregoing results provide evidence demonstrating the close correlation between mean isothermal and isopycnal surfaces. Assuming that Leipper's approximate geostrophic approach could be extended from deep waters to the waters of Monterey Bay, the mean isothermal surfaces would then effectively replace the mean isopycnal surfaces and indicated mean currents could be deduced from them. On this basis,



topographies of the mean monthly isothermal surfaces were assumed to represent mean flow and were portrayed in Figures 34-48.

#### 1. Selecting the Isothermal Surface for Portrayal

The annual variation in upwelling, causing the isotherms to rise and fall through a considerable depth interval, prevents the use of any one isothermal surface for the whole year. Instead, isotherms were chosen for a given month by inspection of selected vertical temperature sections. The isotherm that best described the temperature characteristics of the mid-waters (40-100m) was chosen from the corresponding vertical section. When a shift was made from one isothermal surface to another, both surfaces were drawn to assist in observing continuity. The mid-waters were chosen for two reasons: (1) rapidly changing thermal conditions in the surface waters could be misleading since they did not correlate as well to mean density conditions as did the deeper waters, and (2) the 40-100m region should respond to offshore currents, upwelling, and wind (to a lesser extent) and thus provide mean isothermal surfaces most likely to be related to changes in mean current.

#### 2. Description of Figures 34-48

The comments in paragraph III. E.1 concerning location of data points, mean winds, and mean offshore currents are applicable to these figures as well. The number of temperature values used to compute the mean temperatures for each block are listed in Table I (the values at 50m are representative of those throughout the mid-waters).



Topographies of the mean isothermal surfaces were contoured at 10m intervals. Dashed lines indicate probable extensions of contours where data was not available. Depth contours of isothermal surfaces are portrayed only in regions of the Bay where depths of water are greater than or equal to the values of the contours. The termination of a given contour is shown by a short segment of the equal valued bottom contour drawn across it.

The letter H (high) indicates the greatest depths of the isothermal surface and the letter L (low) indicates the shallowest depths.

#### D. MEAN CURRENTS INDICATED BY THE ISOTHERMAL SURFACES

In considering the indicated mean currents it should be emphasized that the results are based on the combination of data compiled from 1929 through 1968. The various regions of "highs" and "lows" appearing on the mean monthly isothermal surfaces (Figures 34-48) cannot be considered as fixed. Skogsberg [1936] showed that internal waves and advection, acting in the southern portion of the Bay, caused daily (and even hourly) changes in the thermal structures. For any given month the contours vary from day to day and also from year to year, and therefore, the figures are useful as indicators of the average thermal conditions and not the conditions for any given time.

Since it was assumed that the topographies of the mean isothermal surfaces represented mean flow (see paragraph C), the following rules apply: (1) mean circulation is counter-clockwise about regions marked with an L (cold water, high



mean density regions), and clockwise about regions marked with an H (warm water, low mean density regions), (2) mean flow follows the contours with the colder water always to the left, and (3) stronger currents are indicated by closer spacing of the contours, and conversely.

The indicated mean currents (inferred from Figures 34-48) are discussed below. To prevent repetition, the term "mean flow" will be used to imply indicated or inferred mean flow and the term "intensity" (or "strength") will imply the relative intensity based on the spacing of contours.

#### 1. Intensities of Mean Flow in the Bay and Offshore

The intensity of mean flow (I) in the Bay is represented by a formula relating it to contour spacing as follows:

$$I = \Delta D / 5L$$

where,

I = Intensity of mean flow in mi/day,

$\Delta D$  = The difference in depth (m) between contours,

L = The measured length (in) between contours.

The factor of 5 (in the denominator) was applied to make the annual range of I agree with the annual range of mean offshore current (mi/day) as found in H.O. 507 (see Figure 31). The values of I plotted in Figure 31 represent the maximum intensities (minimum spacing of contours) for a given month. Thus, the assumption is made that the strongest monthly average currents in the Bay are equal to the average currents offshore. Months where two isothermal surfaces are portrayed are represented by an average value of I.





The annual cycle of the mean offshore current (dashed line in Figure 31) was divided into two periods. The California Current prevailed from February (mid-points of the months are plotted on the abscissa) until early November, the Davidson Current prevailing the remainder of the year. The annual cycle of mean current intensity in the Bay shows peaks in December, March, and August. The peak in December and the general shape of the curve from November to February is similar to that of the offshore Davidson Current. The peaks in March and August do not appear to be related to peaks of the offshore current; in fact, the shapes of the Bay and offshore curves approach that of a mirror image during the period from March until August. These peaks appear to be related to upwelling and are discussed in subparagraph 2 below.

## 2. Annual Variations of Mean Flow in the Bay

Inferred mean flow is depicted by arrows with the intensity of flow (I) indicated to the nearest whole number (mi/day) in Figures 34-48).<sup>4</sup>

### a. November to February (Figures 47, 48, and 34)

The variations in intensity of flow (as noted above) are similar for the Bay and the offshore Davidson Current prevailing during this period. As described in paragraph A.1, a north-flowing offshore current is considered by some to generate a clockwise driven current within the Bay.

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<sup>4</sup> In this case, the value of I (shown in the Figures) represent relative intensities at given locations and not the maximum monthly values.



Referring to the mean isothermal surfaces, the current patterns exhibit this clockwise tendency throughout the period, suggesting that the Davidson Current might be the primary generating force.

In November, the mean flow enters the Bay from the south and spreads into the northeast region with a broad clockwise movement indicated in the center region. Flow then exits from the northern region of the Bay (note the 40m contour).

In December and January, the same general clockwise tendency of flow is indicated. However, the flow appears to enter from the northern region and exit from the southern region of the Bay. The difference in entry points could be due to the offshore current intensity which increases from 1 mi/day in November to 3.4 mi/day in December and January.

b. February to April (Figures 35-37)

In February, the "high" (located near the center of the Bay) intensifies and the resulting intensity of flow doubles over that in January. Flow appears to enter and exit from the northern region following a well defined clockwise path throughout the Bay. The clockwise tendency of flow could not have resulted from offshore current generation since the direction of the offshore current is away from and nearly perpendicular to the coast (and also at its annual minimum speed of 1 mi/day). The maximum rates of upwelling occurring in February and March (as discussed in Chapter III, paragraph B) may explain the inferred clockwise



tendency of the currents. As previously postulated, the spreading or up-surge of the cold waters from the Canyon into the Shallows regions cause a relatively warm tongue (high) in the Canyon region. The high established by this up-surge might tend to overshadow the influence of the weak flowing California Current during February.

The 10°C and 11°C isothermal surfaces were constructed for March. Both have similar patterns but the gradients are stronger at the greater depths (10°C surface, Figure 37). This further indicates the influence of upwelling since upwelling rates are maximum from 60-100m. The currents indicated by the 11°C surface (Figure 36) enter the Bay from the south and follow a snake-like pattern before exiting from the northern region. The 10°C surface (Figure 37) exhibits the same general isothermal structure except there is another well formed low observed in the northern region and the overall intensity of flow is greater. The development of the "lows" in March could be caused by an influence of the California Current which had increased to 5 mi/day (near its annual maximum intensity). The influence, by the theory of offshore generation, would be to cause a counterclockwise gyre within the Bay which would agree with formation of a "low." This was not indicated to be a major feature by the isothermal topographies.

c. August to October (Figures 42-44)

This period is discussed next because the mean flow in the Bay is believed to be a result of conditions similar to those described above. August and September (the



months of maximum rates of downwelling) showed the same dipping of isotherms across the Canyon and the same relative warm spots in the Canyon region as were observed during February and March. The possible relationship was discussed in Chapter III, paragraph B. The well established highs in August and, for the 10°C surface, in September (the deeper surface where downwelling rates are also greater) demonstrate the possible influence of downwelling. Current trends are clockwise (as in February and March) and thus opposite to the currents theoretically predicted due to influence by the California Current. On the other hand, the 11°C surface (shallower waters) in September exhibits more complex trends that could have been partly influenced by the California Current. Current patterns are counterclockwise in the middle and northern regions and a clockwise trend is observed in the southern region. Downwelling is weaker above 50m (in September) and apparently does not exert as great an influence on the indicated currents. It was also observed that flow indicated by the shallow waters (11°C surface) is nearly opposite in direction to that indicated by the deeper waters (10°C surface). Since the whole region of the midwaters (40-100m) is assumed to represent the indicated currents, it is concluded that the shallow and the deep surfaces (in September) combined in some fashion to represent mean flow. The best approximation of the mean flow is thus a combination of flows inferred from both surfaces.







d. October (Figures 45 and 46)

The current trends indicated by the 11°C isothermal surface are similar to those of the 11°C surface in September (Figure 44). Flow enters the southern region of the Bay, follows an "S-shaped" path, and exits from the northern region. The high observed in the southern region appears to be a holdover from the high observed during July and August.

The 12°C surface (Figure 46) is generally similar to the 11°C surface except the high is absent. The general counterclockwise trends (especially for the 12°C surface) conform to the theory of generation by an offshore current.

In general, it appeared that weaker offshore currents came into the Bay, while stronger currents caused a reverse eddy within the Bay.

e. April to August (Figures 38-41)

The intensity of indicated mean flow is low throughout this period. Figure 31 shows the weak mean currents which decrease to an annual minimum in June.

Current trends in April are similar to those in March (Figures 36-37) but the intensity of flow is only half as great. The weakening of the high in the center region corresponds to the decrease in the rate of upwelling which ends altogether in May to June. The low in the southern region remained the same strength as it was in March but intruded further into the Bay (as noted by the 40m contour in Figure 38).



The indicated mean flow during May is almost due south, dipping into the Bay and broadly following the shoreline. The direction of flow corresponds closely to the direction of mean offshore current in the central and northern regions and tends seaward in the southern region.

A high develops in June which extends throughout the Bay. Mean flow enters the Bay from the north and follows a broad clockwise path, exiting also from the northern region. Intensity of mean flow is at its annual minimum in June.

The high persists in July and a low is seen to develop in the northern region. Flow enters the Bay from the north and is observed to exit from the southern region.

The development of the high in June and its subsequent strengthening from June through August (Figure 42) could have been partly due to downwelling which commences in June and ends in early November (see Chapter III).

In summary, the inferred mean flow in the Bay is based solely on the topographies of mean monthly isothermal surfaces. Inferred current trends could be related to generation by offshore currents only during the Davidson Current Period and possibly in the month of May. Trends of inferred current during the remainder of the year appear to be influenced more by up/downwelling than by offshore currents. The possibility of up/downwelling exerting a greater influence than offshore currents on mean flow is difficult to test and verify. However, the maximum intensity of mean offshore current during any month of upwelling or downwelling



is only 5 mi/day (about 1/5th of a kt), and the annual maximum reaches only 6.7 mi/day. Thus, it would appear that the relatively small horizontal density changes (assumed to be mainly a result of the surging of the cold waters during up/downwelling) between the waters of the Canyon and those of neighboring shallow areas could be equally (if not more) responsible for influencing mean Bay currents. The above phenomena are of course, related in some complex manner.

There is insufficient data concerning previously measured currents in the Bay to verify the influence of up/downwelling on Bay currents. However, the author found several limited current studies which could be compared to the inferred Bay currents of this report.

#### E. COMPARISONS OF INFERRED MEAN CURRENTS TO PREVIOUSLY MEASURED CURRENTS

Comparisons between the inferred mean monthly flow (based on many years of data) and several short term (6-48 hours) current measurements during a given month cannot be expected to show more than broad agreement for specific times. The positions of the highs and lows (and hence the distribution of indicated current) on the mean isothermal surfaces for a given month represent the most likely conditions over a long time period and not those for a given day of the month, or even for a given year for that month. Finally, the short term currents must be considered only as general trends since their directions and speeds are heavily influenced by tidal forces and local winds. The following comparisons are more encouraging than the above limitations suggest.



### 1. March

Stevenson [1964] deployed three surface drogues in early March from a location 1/2 mi offshore in the southernmost area of the Bay. All drogues moved shoreward (until beaching) as shown by the dotted arrows in Figure 36. The shoreward movements of the drogues would appear to agree with the inferred currents which tend shoreward in the region where the drogues were deployed.

### 2. July

McKay [1970] conducted current measurements in late July using a Geomagnetic Electrokinetograph (G.E.K.). The measured currents (indicated by dotted arrows in Figure 41) did not fully agree with the plotted indicated current patterns; however, the position of the "low" in the northern region would support such current movement. The shape of the "low" could not be determined since there was no data for adjacent blocks to the north and east.

### 3. August

McKay conducted current measurements with the G.E.K. in early and mid-August, 1969 (solid short arrows in Figure 49) and Stoddard [1971] employed surface drogues in mid-August, 1970 (dotted arrows).

#### a. McKay's G.E.K. Measurements

The shorter solid arrows represent individual G.E.K. measurements. Considering the region bounded by the 60m and 80m contours, the correlation of the measured currents to the inferred mean currents is very close, with







about 3/4ths of the G.E.K. measurements observed to follow the contours. In the region bounded by the 80m contour, the measured currents broadly exhibit a clockwise motion with a general confusion in direction noted (which agrees with the plotted position of the high).

The G.E.K. measurements to the south of the 60m contour appear somewhat confused in direction when considered as a whole. The arrows with tails represent measurements taken on 5 August while all other solid arrows represent measurements taken from 11-12 August. During 11-12 August the measured currents in the extreme southern region are seen to move northward and then to turn towards the west. This trend would appear to agree with the mean flow which exits the Bay (between the 50m and 60m contours) from the southern region and could force the northerly current to turn westward. The currents measured on 5 August tend towards the southwest which could be due to the conditions such as displayed by the isothermal surfaces in July (note the 30m contour in Figure 41). Since all surfaces are assumed to represent the mid-month conditions, the mean flow in July might influence that in early August. The above discussion is conjectural since insufficient data is available to construct contours in the region of interest. The intention is to show that the current trends by McKay in this (southeastern) region show plausible agreement with those inferred from the isothermal surfaces. The measured current velocities were all significantly higher than inferred



values (I). This is as expected since they were virtually instantaneous measurements.

#### b. Stoddard's Drogue Study

The longer dotted arrows in Figure 49 represented surface drogue tracks. Six drogues were tracked for about 17 hours and one (the southernmost shorter track) was tracked for 7 hours.

The two tracks in the region bounded by the 70m contour follow definite clockwise gyres, not too far removed from the location of the high (generally agreeing with its plotted position). The remaining tracks do not correlate with mean flow; in fact the three tracks to the south are nearly 180 degrees out. Data was not available during August in Blocks 10, 11, 14, and 21S (see Figure 1) and therefore, the isothermal surfaces (as shown for this region) could be in error.

#### 4. September

Stoddard tracked six surface drogues in late September, 1970. The tracks show good correlation to the shallower 11°C isothermal surface (Figure 44) but generally are not well related to the 10°C surface (Figure 43). The following discussion is based on comparison to the 11°C surface (although the best approximation of indicated mean flow would lie somewhere in between the two surfaces).

The duration of the drogue tracks varied from 12 to 25 hours. The author computed the speed of each drogue based on the distance made good from deployment until the end of tracking. The average value of the six speeds was 2.75 mi/day



which compared favorably to the arbitrary value of I for September of 3.6 mi/day (Figure 31). The value of I represents the maximum mean intensity (minimum contour spacing) for a given month, and was made to agree (in total range of values) with the intensity of mean flow for the offshore current (see paragraph D.1).

Drogues 1-3 (see circled numbers adjacent to dotted arrows in Figure 44) all exhibit clockwise trends which broadly agree with the location of the high in the southeastern region of the Bay. Closer correlation is not possible since no data exists in the block to the right of the high (shown crossed out in Figure 1).

Tracks of drogues 4 and 5 cut directly across the 40m contour; however, their tendencies to move to the right when seaward of Point Pinos agree with the general mean current patterns (note the north-flowing mean current which would force the currents indicated by tracks 4 and 5 to the right).

The track of drogue 6 agrees with indicated mean flow, following the 40m contour and tending in a slight clockwise path. The speed of drogue 6 (computed as above) was computed to be 4.1 mi/day versus an arbitrary value of I equal to 4 mi/day in the same region.

## 5. October

Stoddard tracked four surface drogues in early October, 1970. The tracks show excellent correlation to the shallower 12°C surface (dotted arrows in Figure 46) and fair correlation to the 11°C surface (Figure 45). Drogue 3 was



tracked for 10 hours and all other drogues were tracked for only six hours. The average computed speed for drogues 1, 2, and 4 was eight mi/day, while drogue 3 made good a speed of 6 mi/day. The speeds inferred from contour spacing are only 2 to 3 mi/day. Since the duration of tracking was short, the effects of the tidal currents (and local winds) could have introduced considerable influence on the speeds and directions of the drogue tracks.

All drogue tracks broadly followed the 30m contour (Figure 46) and all except drogue 3 moved in a direction related to the indicated mean current. The path of drogue 4 almost exactly agrees with the indicated flow.

#### 6. November

Stoddard tracked eight surface drogues in mid-November, 1970 (shown by solid, dashed, and dotted arrows, numbered 1-8 in Figure 50). The duration of tracking varied from 6-42 hours. The computed speeds (again based on distance made good per total tracking time) are listed below:

Drogue No.	Duration of Tracking (hr)	Computed Speed (mi/day)
1	42	5.7
2	22	3.9
3	21	1.2
4	23	3.4
5	7.5	11.2
6	6.5	14.1
7	6.5	10.7
8	6	10.8

The consistently greater speeds for drogues 5-8 were probably due to tidal currents prevalent in the short







duration of tracking time and were thus disregarded. Drogues 1-4 exhibited speeds closely related to the arbitrary value of  $I$  for November. The combined average speed of drogues 1-4 was 3.6 mi/day while the arbitrary maximum value of  $I$  was 4.2 (Figure 31). The average value of  $I$  for November would be somewhat lower (but nearly impossible to estimate from contour spacing alone).

The tracks of all drogues exhibited clockwise tendencies which correlated with indicated mean current about the extensive high in the center of the Bay. The individual tracks of drogues 1 and 8 closely approximate the indicated mean current while the remaining drogues showed fair correlation (Figure 50).

It is noted that the speed of drogue 3 (1.2 mi/day) is significantly lower than the speeds of drogues 1, 2, and 4. Also, the track of drogue 3 describes a tight clockwise path which is not the case for the other tracks. This led the author to believe that drogue 3 might have been nearer the center of a high than is shown in Figure 50. It is assumed that the high (and the entire mean isothermal surface as well) could probably vary in location from day to day (and year to year) for a given month. On this basis, the mean isothermal surface for November was translated to a position where the high overlayed the track of drogue 3. The distance of translation was 3 mi in a west-southwest direction. Figure 51 shows the results of the translation. All drogue tracks are now observed to closely follow the



translated contours and the correlation to indicated mean current is excellent.

#### F. SUMMARY

The general agreement between measured currents from past studies and indicated mean currents for this study is encouraging. The total number of comparisons made is far from that required to fully substantiate the inferred mean currents of this study; however, the comparisons do lend considerable support to the feasibility of using mean isothermal surfaces as indicators of mean flow, which was a primary objective of this study.



## V. CONCLUSIONS AND RECOMMENDATIONS

### A. CONCLUSIONS

1. Progressive warming with time is indicated throughout Monterey Bay, mainly occurring at depths from the surface to 300m. The temperature was noted to increase as much as 1.8°C over the 29 year interval from 1931 to 1960.

2. The intensity of upwelling varies in different geographic regions of the Bay. This variation in the maximum rates of upwelling (and downwelling) is believed to be a major factor controlling the shapes of mean isothermal surfaces (and indicated mean currents as well) during the months of maximum up/downwelling.

3. The method of using mean isothermal surfaces as indicators of mean current shows promise. The comparisons of inferred mean flow to direct current measurements (as shown in Figures 34-48) demonstrates general agreement between the two.

### B. RECOMMENDATIONS

1. The data collected throughout Monterey Bay is insufficient for several of the blocks in the author's grid system (Figure 1). To obtain a more complete picture, both in the mean monthly sea surface temperature distribution and in the topographies of mean monthly isothermal surfaces, a continued search of data for the following blocks would be beneficial: 7, 8, 9, 10, 11, 14, 16, 18, 21S as well as the block shown crossed out in Figure 1.



2. Future studies should be made of the mean monthly current distribution in the Bay (the author was unable to locate any previous work in this area). Whatever methods are used in the future might be compared to the mean flow inferred in this study for purposes of attempted verification.

3. To aid in the future study of oceanographic parameters (in general) of Monterey Bay, a computer storage and retrieval system should be instituted and maintained on a continuing basis. An example of a computer system designed for this purpose is presented in Appendix B (the "final computer program, number 11").

Closer coordination with NODC is required of all oceanographic facilities so that the oceanographic data collected in Monterey Bay over the years can be made available to any investigator desiring its use.





## APPENDIX A: DATA SOURCES

### A. PROBLEMS ENCOUNTERED

The only previous research found that categorized oceanographic data collected in Monterey Bay was that presented in an NPS research paper by P. M. Magruder, Jr., [1969].

Magruder's paper was most beneficial in delineating the major sources of data. Many reports were located covering related subjects such as biology, sound velocity variation, and light attenuation studies. Many of these reports used temperature and salinity data. However, the data was generally not contained therein, nor is there any reference to its location in some reports. There is a general lack of continuity in reports which contained temperature and salinity data. Methods of collection were sometimes omitted and very seldom was there any information describing environmental conditions, etc.

### B. MAJOR DATA SOURCES (FIGURE 3)

#### 1. Bolin Data

Rolf L. Bolin and collaborators [1964] collected Nansen samples over a five year period from 1951-1955 at the position 36-42N, 122-02W. Casts of 24-bottles were generally employed to depths of 1000m at weekly intervals. A total of 233 casts were made and analyzed for temperature, salinity, and other chemical parameters. A copy of this report is on file at the Naval Postgraduate School Library.



## 2. Fleet Numerical Weather Center (FNWC) XBT Data

Nansen cast, bathythermograph (BT), experimental BT (XBT), and message BT data are on file at FNWC. The Nansen cast and BT data are also filed at the National Oceanographic Data Center (NODC) and are kept more completely there.

FNWC is presently digitizing the XBT data for inclusion in computer tape files at NODC. Two 9-track computer tapes (NPS 264 and NPS 265), held by Dr. Denner at the Naval Postgraduate School Oceanography Department, contain the world oceans XBT data which consists of about 40,000 individual stations. A computer program (see article B.2, Appendix B) written by the author reveals only 43 XBT stations scattered randomly throughout the Bay. There have been considerably more than 43 XBT drops in the Bay over the last three years but the data is not as yet available.

## 3. Hopkins-CalCOFI Data

Hopkins Marine Station has conducted a continuous hydrobiological survey of Monterey Bay for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) since 1951. Commencing in March of 1954 the data (unpublished) was tabulated and distributed in annual reports containing monthly averages of Bucket, Nansen, and BT temperatures, salinities, and densities ( $\sigma\text{-T}$ ) for six oceanographic stations in the Bay. The averages were based on approximately weekly visits to each station; [Hopkins 1954-1967].



a. Ocean Temperatures

Surface temperatures were read from a bucket thermometer and BT data was listed at 10m intervals from the surface to 50m for stations 2, 3, 4, and 6, and to 30 and 20m for stations 1 and 5, respectively. This data was not computerized since the majority of it was included as NODC-BT data in paragraph 4 below.

b. Salinity and Sigma-T Data

Nansen samples taken at the surface and 15m were titrated for chlorinity and thence salinity and sigma-T were determined. Temperature, salinity, and sigma-T were tabulated along with their monthly averages for each station.

4. National Oceanographic Data Center (NODC) Data

Magruder obtained complete printed listings of Nansen cast and BT data from NODC in January of 1969. The area of coverage included Marsden Squares 121 (61 and 62). The listings are available in the NPGS Oceanography files.

For purposes of, (1) rapid computer processing, and (2) updating of data through 1970; magnetic tapes were requested from NODC. Two 7-track tapes were received in December 1970, one listing Nansen cast data in Marsden Square 121(R1019) and the other listing BT data (R1030). The formats of these tapes were different and had to be processed separately (see articles B.4, 5 of Appendix B). The tapes are the property of the NPGS Oceanography Department (see Dr. Leipper).



The total number of Nansen and BT stations within Monterey Bay (retrieved from above tapes) were 107 and 1377 respectively.

a. Nansen Cast Data

The data included temperature, salinity, oxygen, phosphates, silicates, nitrates, and pH as observed parameters. All values were interpolated to standard depths by a three point Lagrange method. Each station is identified by a Master Card, which lists such information as ship name, position, date, etc.

b. BT Data

BT temperatures were listed at 5m intervals from the surface to maximum depth. Each station was again identified by a Master Card.

5. Naval Postgraduate School (NPGS) Data

Four stations were established by NPGS in October 1966. Nansen casts and BT drops were made regularly and all chemical parameters were filed quarterly.

A continuing program of computer processing and filing of data cards for these stations is in progress.

6. Skogsberg Data

Tage Skogsberg [1936] conducted an exhaustive study of thermal conditions in the southern portion of Monterey Bay, collecting over 15,000 samples from 1929-1933. Data included temperature, chlorinity, phosphate, and silicate from 23 separate stations. The original data is on file at Hopkins Marine Station. Skogsberg tabulated monthly temperature





averages for two of his stations, both of which were used in the author's analysis (Chapters III and IV).

## 7. Sea Surface Temperatures

### a. Hopkins Marine Station

Sea surface temperature and salinity has been measured daily at the station since 1919. All records are filed by Hopkins and monthly averages are published by Scripps Institution of Oceanography under the title: "Data Report, Surface Water Temperatures at Shore Stations, United States West Coast and Baja California."

### b. Santa Cruz

Sea surface temperature has been measured daily since 1956 and data is also published by Scripps under the same title as above.

## C. MINOR DATA SOURCES

The below listed sources comprise data covering either small areas or that limited to only several observations. A complete listing was impossible.

### 1. "Monterey Bay Bibliography" [Baron, 1971]

This comprehensive study was recently completed by the Moss Landing Marine Laboratories' of the California State Colleges. It includes all known scientific literature concerning Monterey Bay. Limited copies are now being published.

### 2. Yeske and Waer Data

Yeske and Waer [1968] studied light attenuation at two stations in the Bay during the period 26 July to 31 August, 1968. A total of 39 Nansen casts were made and BT



drops accompanied each cast. Data was filed with NODC and is contained on the computer tapes referenced in paragraph C.4 above.

### 3. Message BT Data

Very little data was found at FNWC (only 21 stations for all of Marsden Square 121) and none more recent than 1968.

### 4. OC-3520 Data

The Chemical Oceanography Course (OC- 3520) at NPGS sponsors limited duration Bay cruises for students. Various oceanographic parameters are collected and final reports are required. The data is not currently being filed but some of it is available.

## D. DISCUSSION

It was clear that a complete source listing of the chemical parameters in the Bay would be a monumental task. NODC maintains a computer listing of oceanographic data throughout the world's oceans but little of the data collected in Monterey Bay has ever reached there. Only 107 Nansen casts were recorded by NODC for the last 40 odd years, representing a trifle of the data actually collected.



## APPENDIX B: COMPUTER PROCESSING OF DATA

Two major goals were sought in designing the "final computer program": (1) to store temperature, salinity, and density data in a form suitable for the computation of mean monthly averages at given geographic locations, and (2) to design a flexible system for storage and retrieval of various oceanographic parameters on a continuing bases.

The second goal was achieved by designing the "station title card" in such a manner that a simple extension could be made to the "station data card" to include additional selected oceanographic parameters without modification of existing formats (see paragraphs A.2.a & b). The institution of such a card system could make the retrieval and usage of oceanographic data from Monterey Bay a very simple task.

### A. STORAGE OF TEMPERATURE, SALINITY AND DENSITY (SIGMA-T) DATA

#### 1. Problems Encountered

About 60% of available data was already in computer format, either on magnetic tape or on data cards. Regrettably, no two formats were consistent. Thus, a separate computer program had to be written to reduce each data source to the author's format. This often included calculation of densities (when they were not included as part of the original format) and always required interpolation of one form or another to place the data at the author's selected "standard depths" (standard depths are listed in Table IV).



The reduction of data already in computer format was actually more time consuming than processing the tabulated data.

The remainder of the available data was tabulated in the various reports cited in Appendix A. First it was keypunched onto computer cards in various formats, depending on the format of the data source. The next step was the printing out of data on computer paper to compare it for accuracy against the original source. After proofreading, computer programs were written to convert the data on punched cards to the desired format. Again, this included calculations and interpolations for the desired results.

The last step in the process was to check the various outputs for correctness and then write the data onto a computer "master tape." Paragraph B describes the various computer programs to the extent of including information not apparent from inspection of the programs themselves.

## 2. Format of the Master Tape

The master tape (NPS serial number 306) served as the storage location for all data processed. The general format of data includes a station title record (identifying the oceanographic station) and a station data record (listing the oceanographic parameters). Table II lists all data contained on the master tape.

### a. The Station Title Record

The station title record allows the flexibility required in general retrieval of data. Referring to Table III, the "80-column record numbers" refer to the inclusive positions on the station title record where the information





TABLE II. Listing of Specific Data Contained on Computer Master Tape, NPS 306

Data Source	Data	Year (incl.)	Remarks
Bolin	T, S, $\sigma_t$	1951-1955	229 Nansen stations
FNWC	T	Various	40 XBT stations
Hopkins-CalCOFI	T, S, $\sigma_t$	1954-1967	972 Nansen stations, each station representing the monthly average of 4 stations at 0 and 15m.
NODC	See Chap II	Various	107 Nansen stations
NODC	T	Various	1377 BT stations
NPGS	See Chap II	Sept 1966- Sept 1967	175 Nansen stations

Note 1: See Appendix A for detailed discussion of data sources.

Note 2: In cases where only portions of a data source were computerized, the year and type of data defines such portions.

Note 3: The "Data Source" is listed by author or collecting activity.



TABLE III. The Station Title Record

80-Column Record No.	Variable	Definition
1-2	NCARDS	The total number of station data records following the title record.
4-7	NANS, XBT, BT, STD	A left-adjusted variable defining the type of data collected.
9-10	NDAY	The day data collected.
12-13	NMO	The month data collected.
15-16	NYEAR	The last two digits of the year data collected.
18-21	NTIME	The time (GMT) data collected. If unknown, NTIME appears as 0000.
24-25	LATDEG	The degrees of station latitude.
27-30	RLATMI	The minutes and tenths of minutes of station latitude.
33-35	LONDEG	The degrees of station longitude.
37-40	RLONMI	The minutes and tenths of minutes of station longitude.
43-45	NWF	NWF=999 specifies Hopkins-CalCOFI monthly average values (4 stations per average).
48-63		Ship name.
----- or, -----		
48-49		NODC country code.
50-51		NODC ship code.
52-55		NODC station I.D. number.
56-59		NODC Stano number.
-----		
65-80	REF	Reference data by author or facility controlling data collection.



was entered. "Variable" was the computer name (applied by author) used in programming. Desired data may be retrieved from the master tape by any one, or any combination of the listed variables. For example, assume an investigator is interested in conducting a study of experimental (XBT) versus mechanical (BT) bathythermograph data in the Submarine Canyon, collected over the last five years. By a series of "computer logical IF statements" [see Blatt, 1968] all station title records are eliminated except those that are either XBT or BT, have geographic positions in the Canyon, and fall within the time frame (NYEAR) of 1966 or later.

b. The Station Data Record

Each station data record contains the standard depth of observation (m) plus one or more of the parameters listed in Table IV above the dashed line. The oceanographic parameters below the dashed line were not included on the master tape but are listed as the recommended additions referred to in the second paragraph of this Appendix.

B. COMPUTER PROGRAMS USED IN DATA STORAGE

Ten computer programs were required to compile the master tape and are briefly described below. The programs will be found in the section entitled, "Computer Programs."

1. Bolin Data

a. Program Number One

Cards were punched from the tabulated data of depth, temperature, and salinity. Program number one calculated densities and linearly interpolated all data to the



TABLE IV. The Station Data Record

80-Column Record No.	Variable	Definition
1-5	STDEP	The author's selected standard depths (m), as: <u>0000</u> . Standard depths used were: 0, <u>10</u> , 15, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, ... , 1400, 1500, 1750, 2000, 2500, 3000, 4000, .. , 6000.
7-11	TEM	The temperature to hundredths of degrees C, as: <u>10.25</u> .
13-17	SAL	The salinity to hundredths of parts per thousand, as: <u>33.65</u> .
19-23	SGT	Sigma-T (density) to hundredths of units, as: <u>26.77</u> .
-----		
25-27	XOXG	Oxygen to tenths of ml per l.
29-31	XPO4	P04-P to tenths of g-at per l.
33-35	XNO2	NO2-N to tenths of g-at per l.
37-39	XNO3	NO3-N to tenths of g-at per l.
41-43	SIO4	SiO4-Si to tenths of g-at per l.
45-47	XPH	pH of seawater to tenths of units.
49-80	---	Can be used for additional storage as required; e.g., computed sound velocity, dynamic parameters, etc.

Note 1: Data above dashed line is included on master tape.  
Data below dashed line is the recommended additions  
for a future storage and retrieval system.





selected standard depths. Linear interpolation was considered accurate since the maximum difference between tabulated and standard depths was only 25m. The final output consisted of computer cards in the format for the master tape.

## 2. Fleet Numerical Weather Center (FNWC) Data

### a. Program Number Two

The existing 9-track tapes (NPS 264 and 265) containing world ocean's XBT data through 1968 were processed. Data in Monterey Bay was retrieved, linearly interpolated, and punched out on computer cards in the format for the master tape. Linear interpolation was exact because XBT data occurred at every depth where temperatures deviated from a linear path.

## 3. Hopkins-CalCOFI Data

### a. Program Number Three

Computer cards were punched from the tabulated annual reports [Hopkins 1954-1967]. Program number three processed the computer cards, linearly interpolated for the 10m values (a selected standard depth), and punched new computer cards in the format for the master tape.

Since each station represented a monthly average value (generally the average of four stations) the data had to be processed differently in the final program. A weighting factor (NWF=999) was added to each station title record and served as a branch instruction to weight this data "four to one" over other data on the tape.



4. National Oceanographic Data Center (NODC) Nansen  
Cast Data

a. Program Number Four

This program read data from a 7-track tape (R 1019), computed the number of station data records following each station title record (NCARDS), and wrote the data (in modified format) onto a 9-track tape (NPS 297).

b. Program Number Five

Data within Monterey Bay was retrieved from the 9-track tape (NPS 297) and written directly onto the master tape in the author's format. One linear interpolation for 15m was required per station, all other data being at the author's standard depths.

5. National Oceanographic Data Center (NODC) Bathy-  
thermograph Data

a. Program Number Six

Data was read from a 7-track tape (R 1030) and written directly onto a 9-track tape (NPS 296). Each station title record contained the number of following station data records, hence, no further programming was necessary.

b. Program Number Seven

Data within Monterey Bay was retrieved from the 9-track tape (NPS 296) and written directly onto the master tape in the author's format. No interpolation was required as data was entered on the tape (R 1030) at 5m intervals.



## 6. Naval Postgraduate School Data

### a. Program Number Eight

This program was written by Robert Middelberg for the Oceanography Department. He was kind enough to allow the author to copy and then modify the program for usage herein. Data cards prepared by Mr. Middleberg were read by the modified program and densities were computed. All data was interpolated to the author's standard depths using Middleberg's "three point Lagrange" method. The Lagrange interpolation method more closely approximates the normal shape of a temperature profile when data is widespread (50-150m between observations) as was the case here. Finally, data was written directly onto the master tape in the author's format.

## 7. Transferring Punched Card Data

### a. Program Number Nine

Program number nine read the punched output from programs 1, 2, and 3 above and wrote it onto the master tape.

## 8. Master Tape Record Count

### a. Program Number Ten

When working with computer tape it is essential to keep an accurate record count of data as it is stored; otherwise, errors that may be made would be nearly impossible to locate. Program number ten was used to keep a running account of data stored and a double check for correct format.



### C. THE FINAL COMPUTER PROGRAM

Program number 11 computes the mean monthly temperatures and densities (at author's standard depths) throughout the Bay, using data from the master tape as its input. Table V defines the output as it appeared on the master printout. Figure 2 shows the initial field of blocks used for the segregation of data. The numbered blocks on the Figure were the only ones containing significant data (at least one month with three or more temperatures in the block). This program will also be found in the section entitled, "Computer Programs."





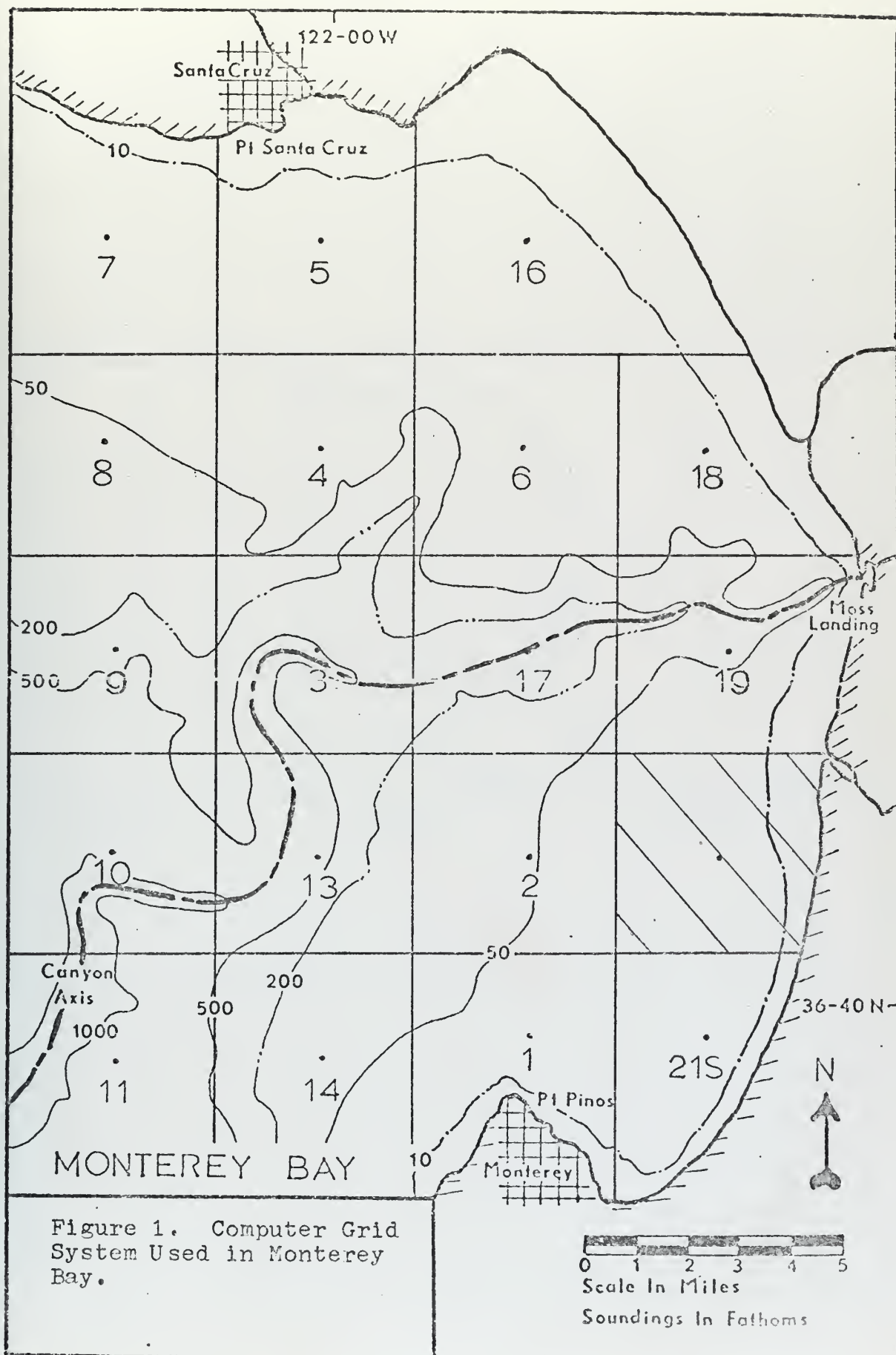
TABLE V: Definition of Computer Variables in the Final Output of Program Number 11

Variable	Definition
TEMP(AV)	The average of all temperatures (weighted and unweighted) for a given block, month, and depth.
SIGMA-T(AVG)	As above for density (sigma-T).
NR WTD VALUES	The number of weighted stations processed.
SUM WTD TEMPS	The sum of all weighted temperature values.
STDEV WTD TEMPS	The computed standard deviation of all weighted temperature values.
SUM WTD SIGMA-T	As above for density.
STDEV WTD SIGMA-T	As above for density.
NR UNWTD TEMPS	The number of non-weighted temperature values.
SUM UNWTD TEMPS	The sum of all non-weighted temperature values.
STDEV UNWTD TEMPS	The computed standard deviation of all non-weighted temperature values.
NR UNWTD SIGMA-T	As above for density.
SUM UNWTD SIGMA-T	As above for density.
STDEV UW SIGMA-T	As above for density.
WTD TEMPS	A listing of all weighted temperature values.
WTD SIGMA-T	A listing of all weighted sigma-T values.
UNWTD TEMPS	A listing of all non-weighted temperature values.
UNWTD SIGMA-T	A listing of all non-weighted sigma-T values.

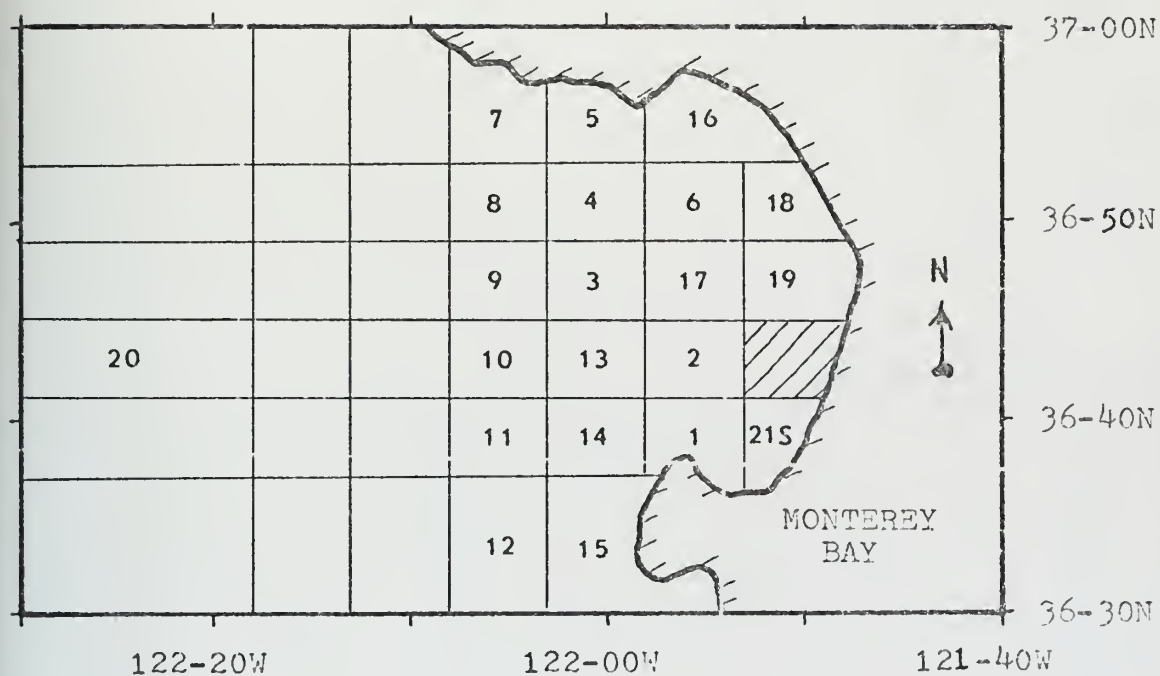
Note 1: All variables above are for a given block, month, and standard depth.



# APPENDIX C



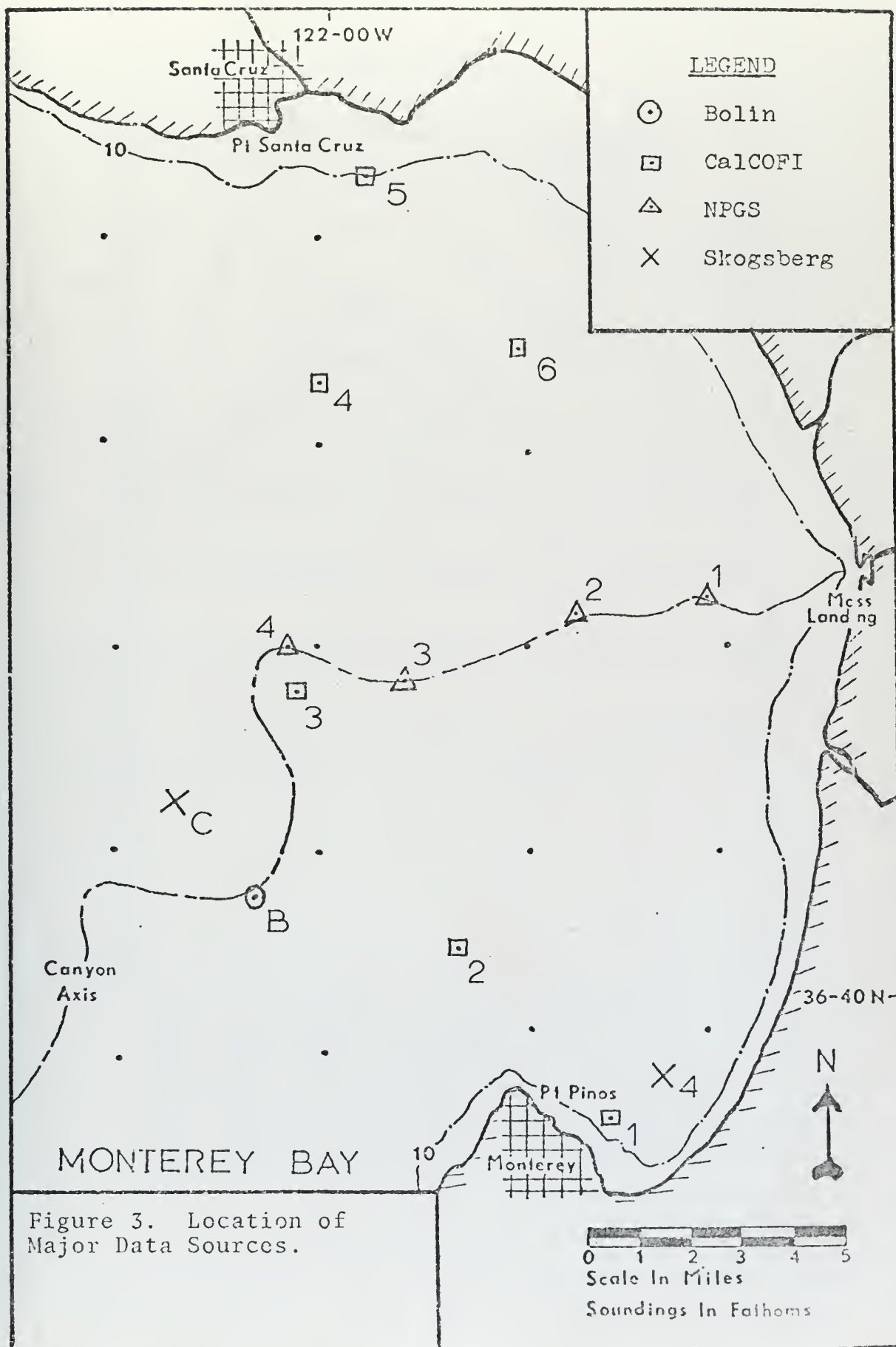




NOTE: Only the numbered blocks contained significant data.

Figure 2. The Initial Computer Grid System.









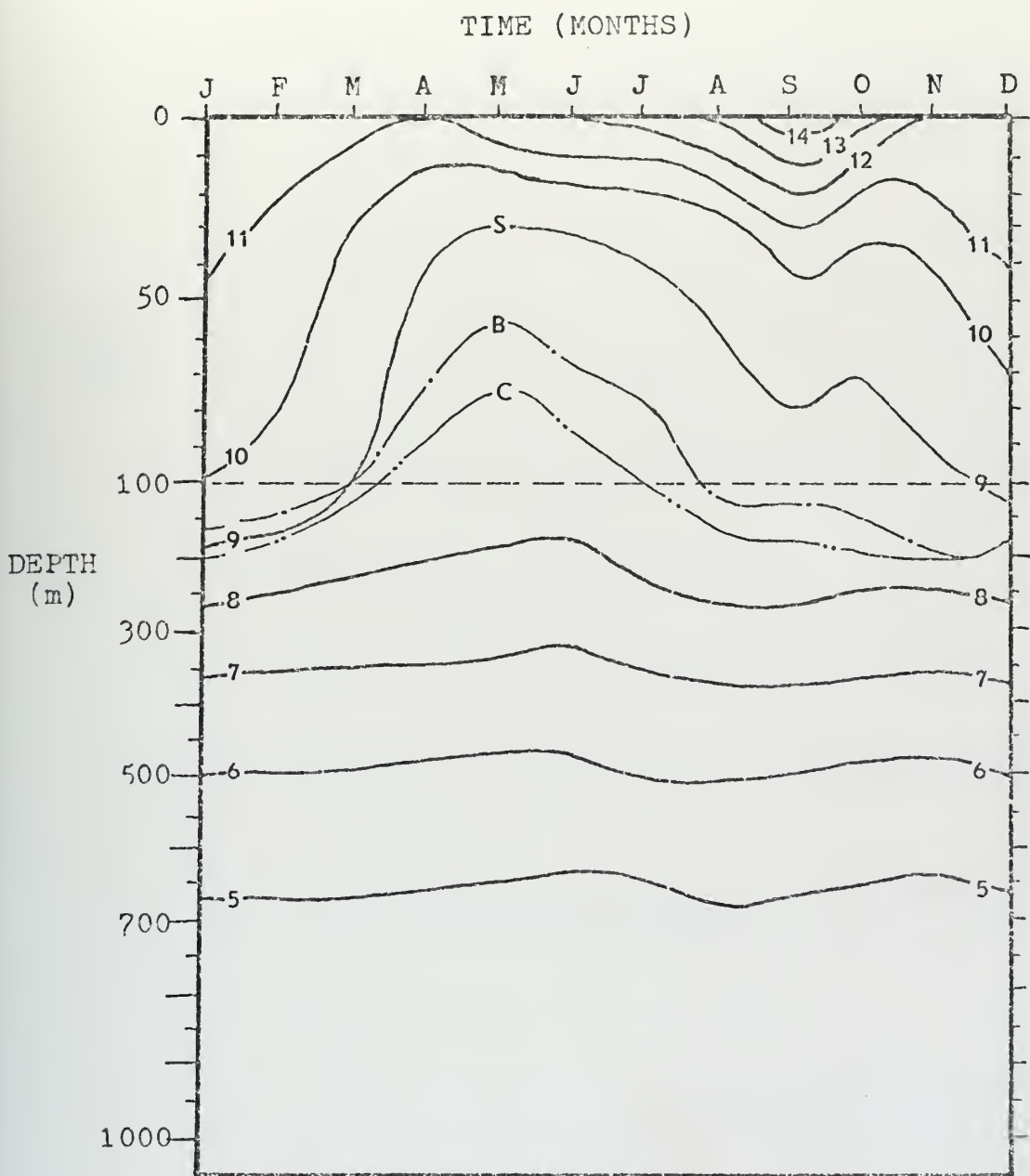
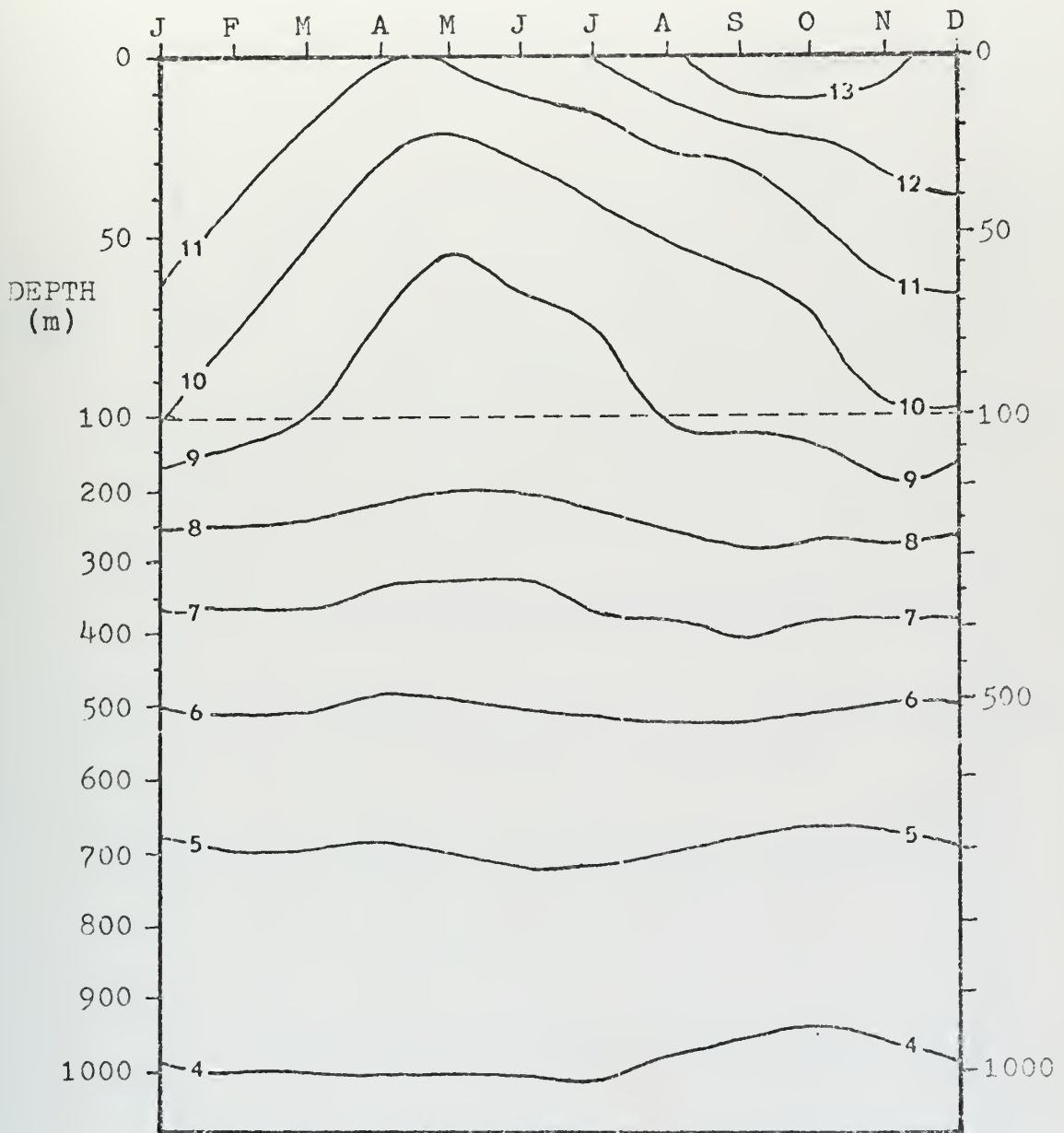


Figure 4. Average annual temperature ( $^{\circ}\text{C}$ ) cycle based on five years of data (upper 100m from 1929-1933, below 100m from 1932-1933) by Skogsberg. Dashed lines note scale change. Note: The  $9^{\circ}\text{C}$  isotherms by Skogsberg (S), Bolin (B) and CalCOFI surveys (C) demonstrate the downward migration of isotherms.



TIME (MONTHS)

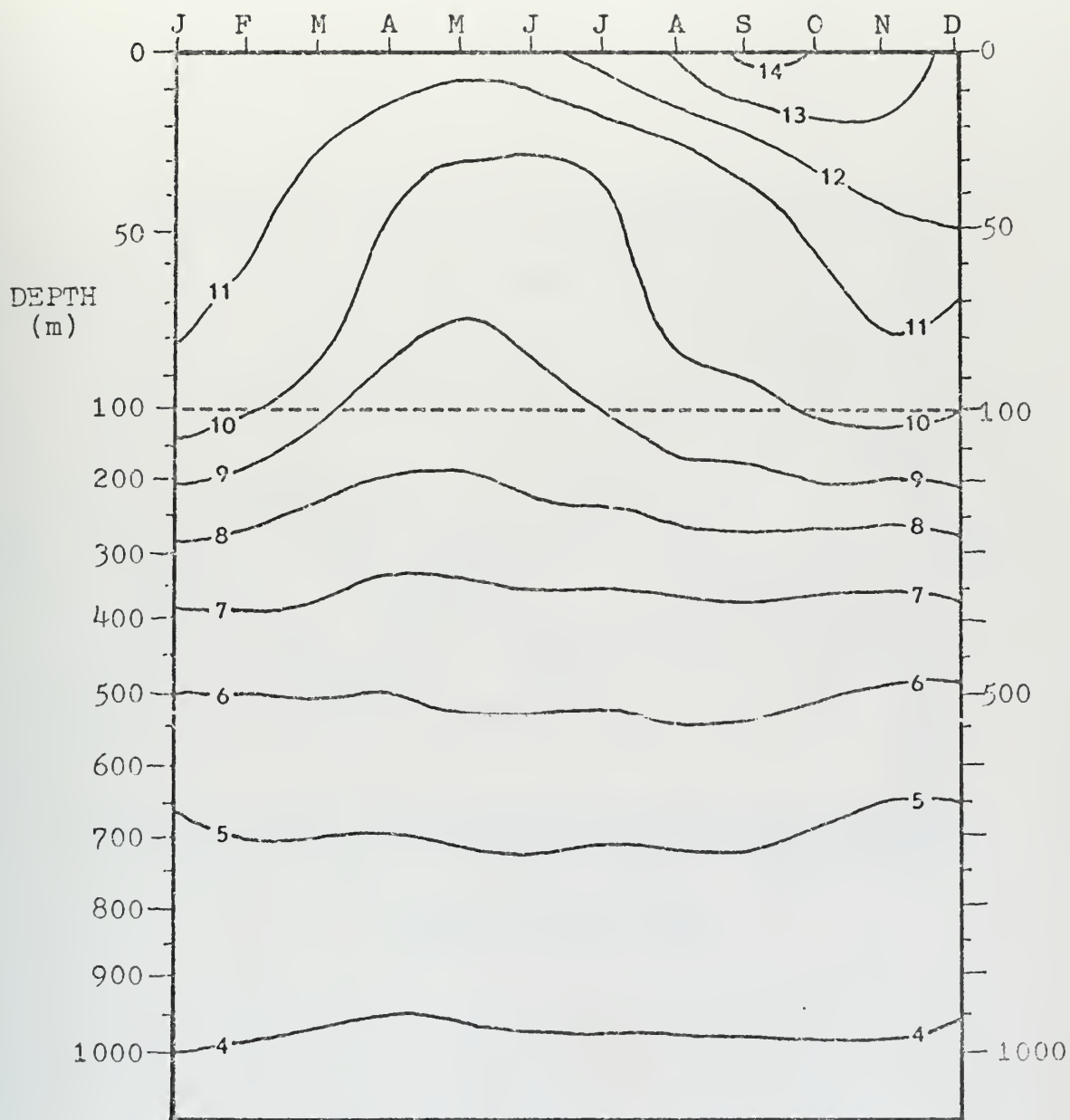


NOTE: Dashed line denotes scale change.

Figure 5. Annual Mean Temperature Cycle by Bolin.



TIME (MONTHS)



NOTE: Dashed line denotes scale change.

Figure 6. Annual Mean Temperature Cycle Based on CalCOFI Surveys.



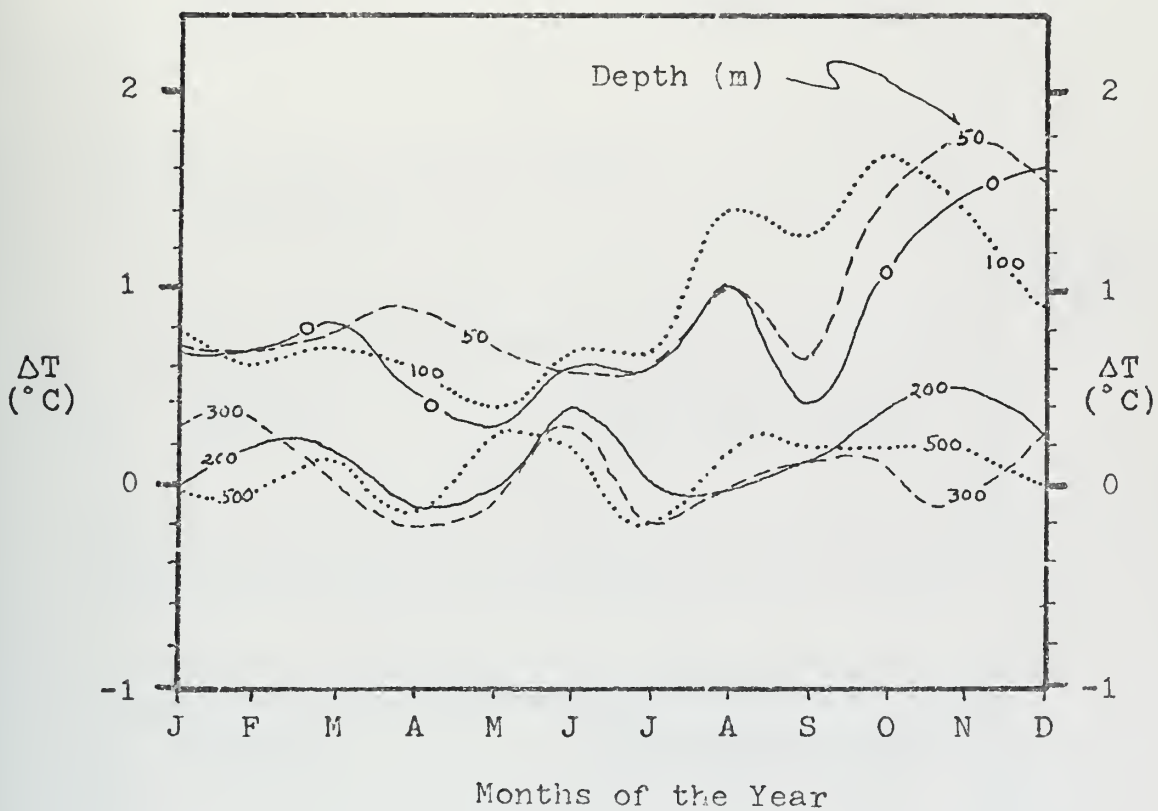


Figure 6A. The Progressive Warming of Bay Waters.





TIME (months)

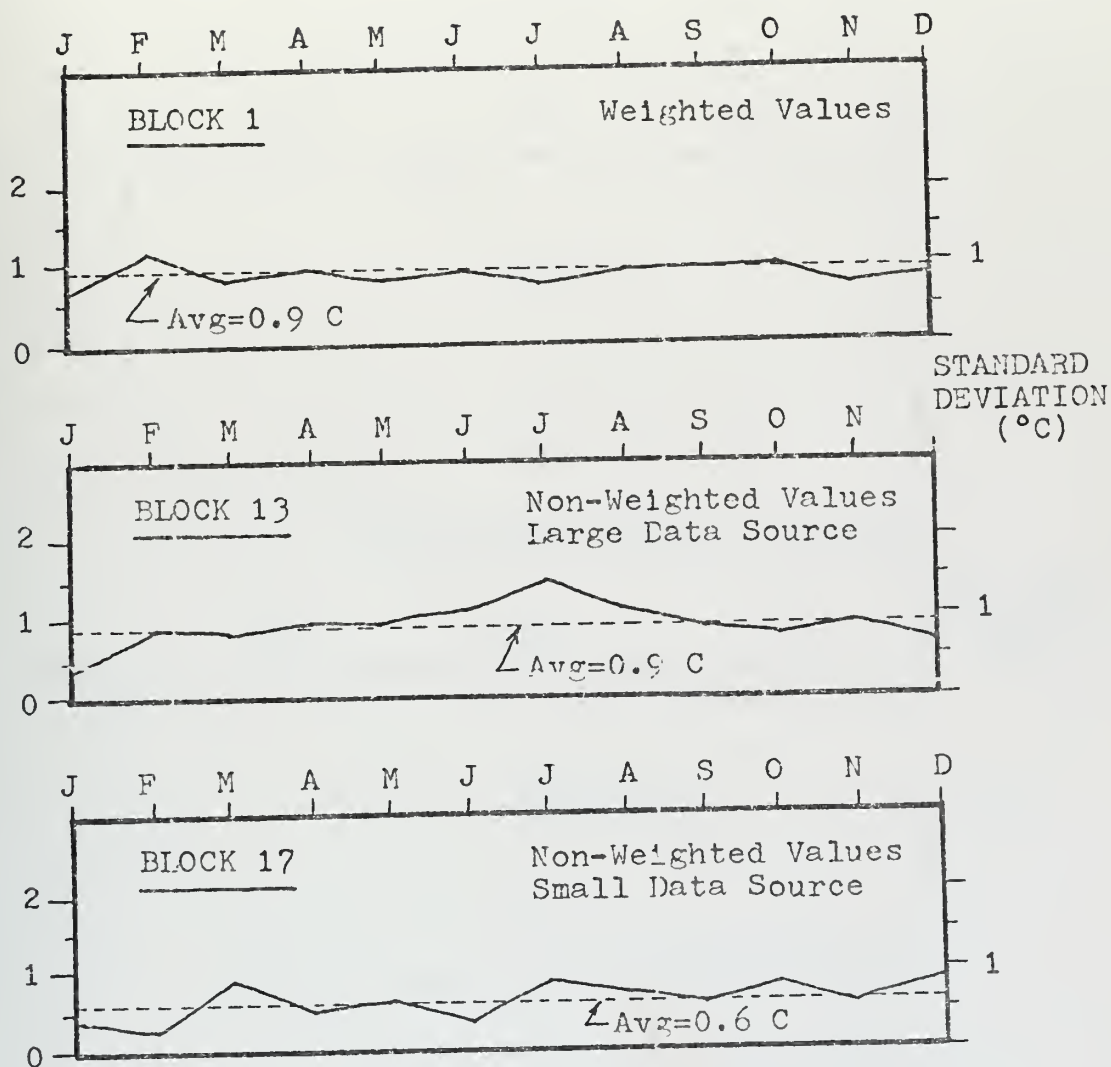


Figure 7. Standard Deviation of Temperature for Selected Blocks as a Function of Time. Sea Surface Temperature.



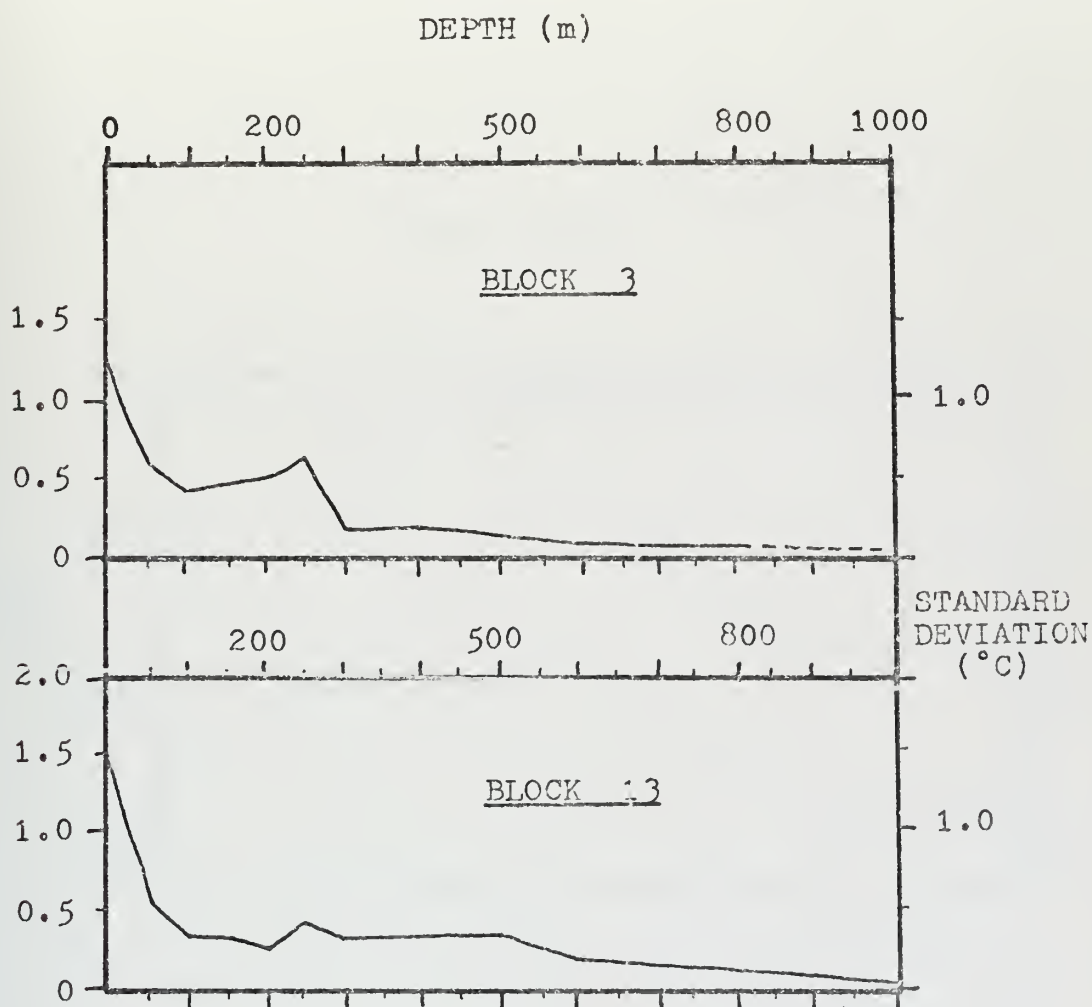


Figure 8. Standard Deviation of Temperature, Averaged in Typical Blocks, as a Function of Depth.



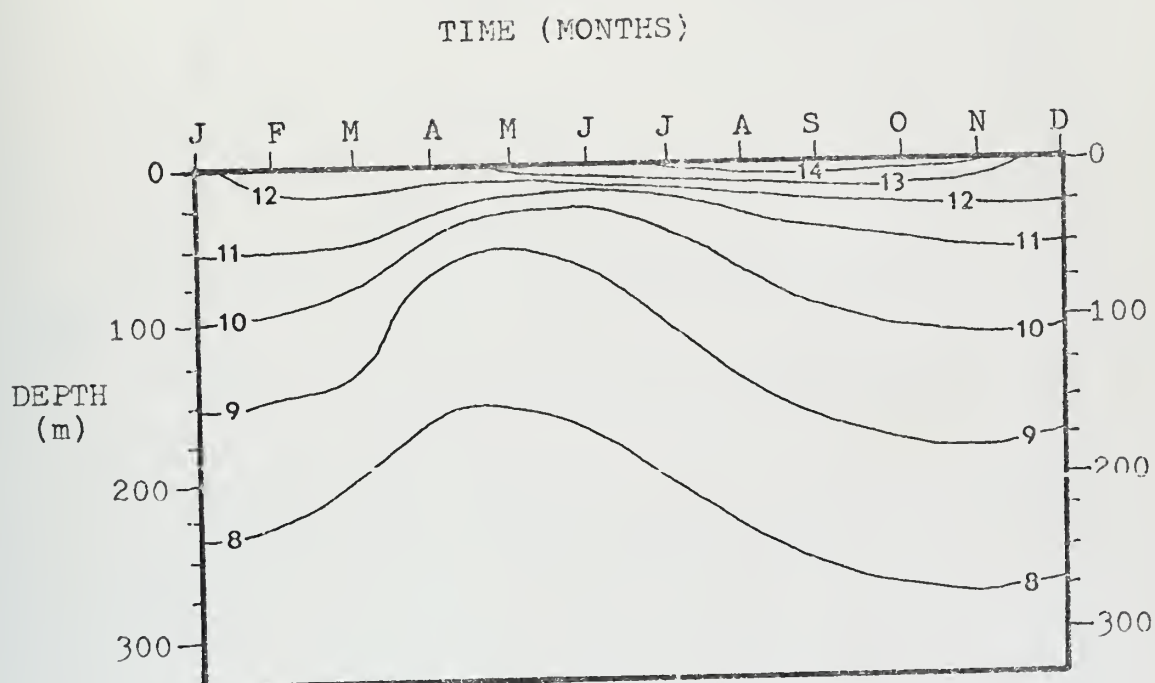


Figure 9. The Annual Mean Temperature Cycle at Block 19.



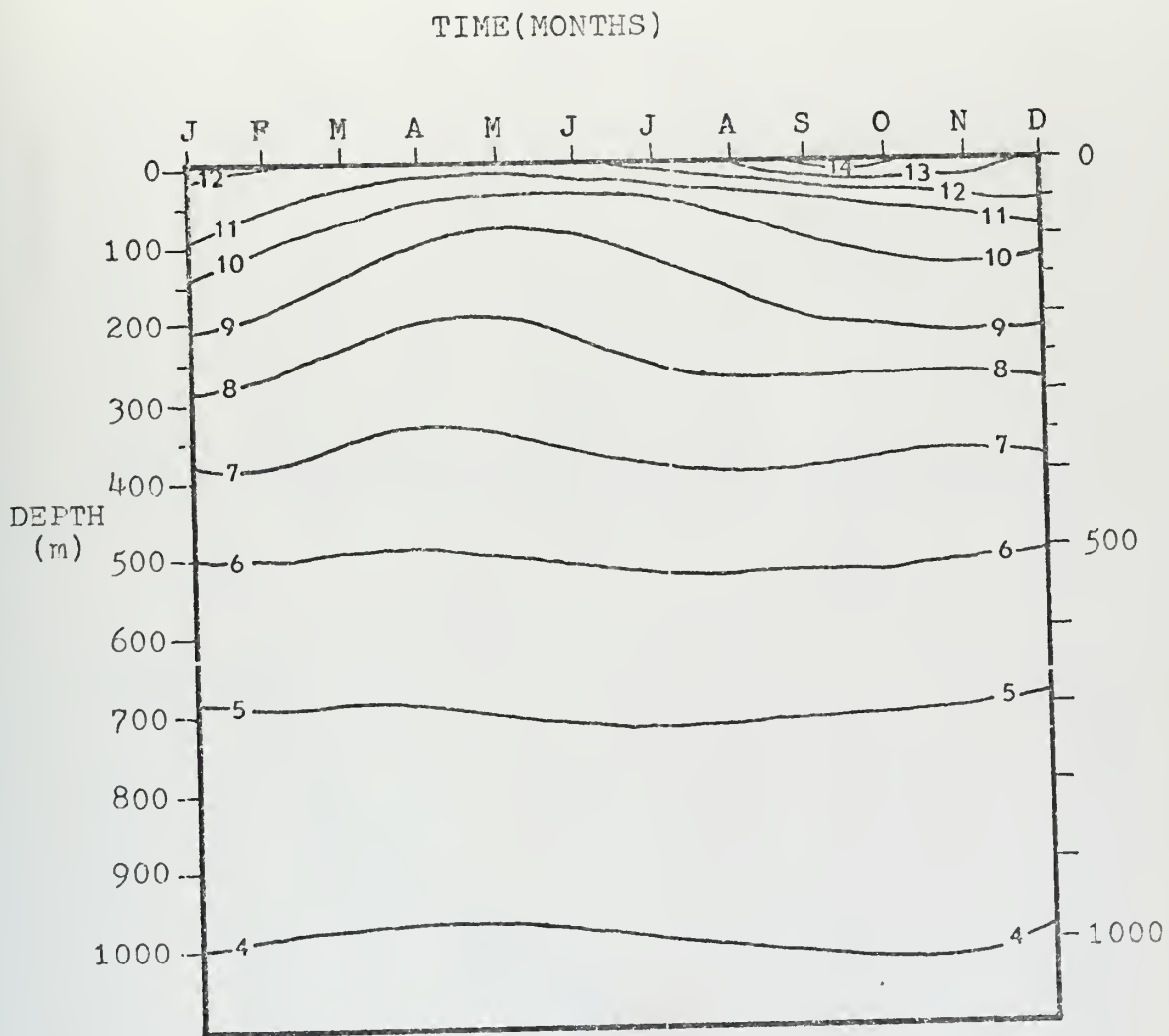
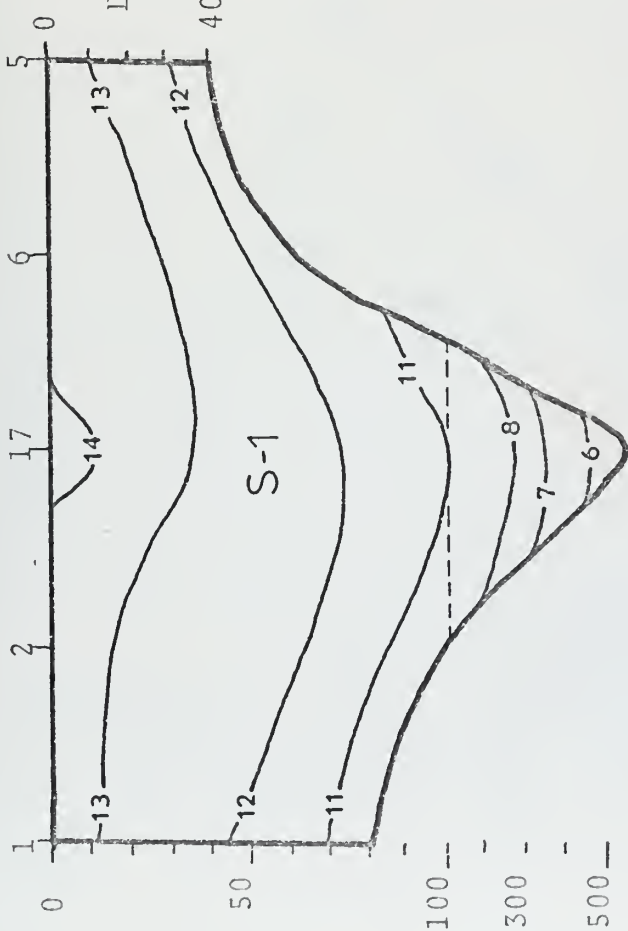


Figure 10. The Annual Mean Temperature Cycle at Block 3.

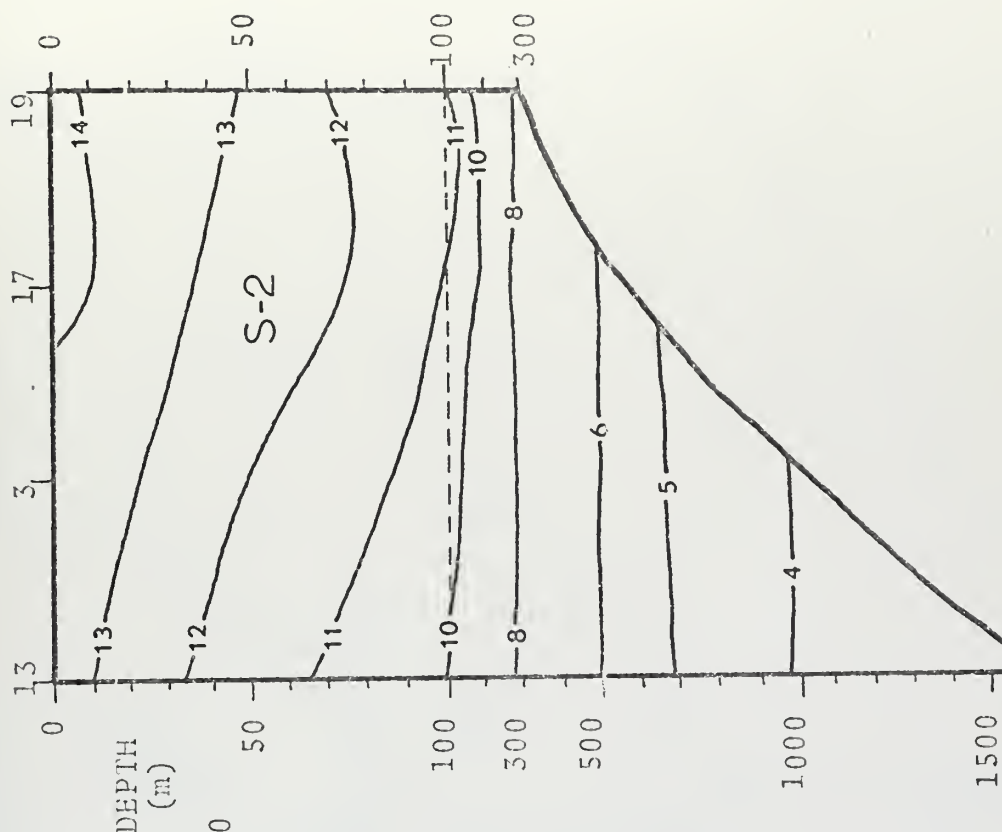




Block No.



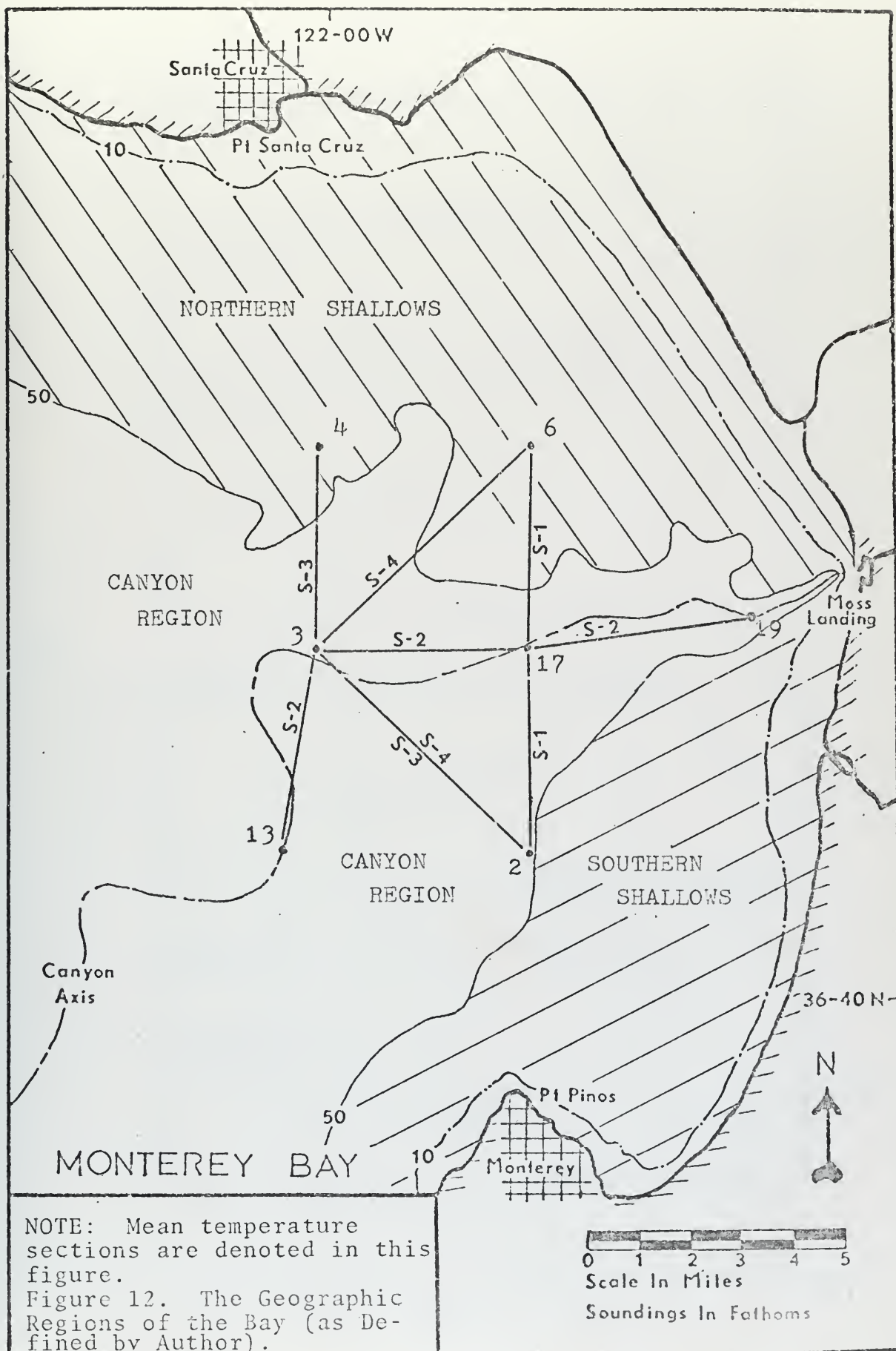
Block No.



NOTE: Dashed line denotes scale change.

Figure 11. Vertical Mean Temperature Sections S-1 and S-2 for the Month of November.







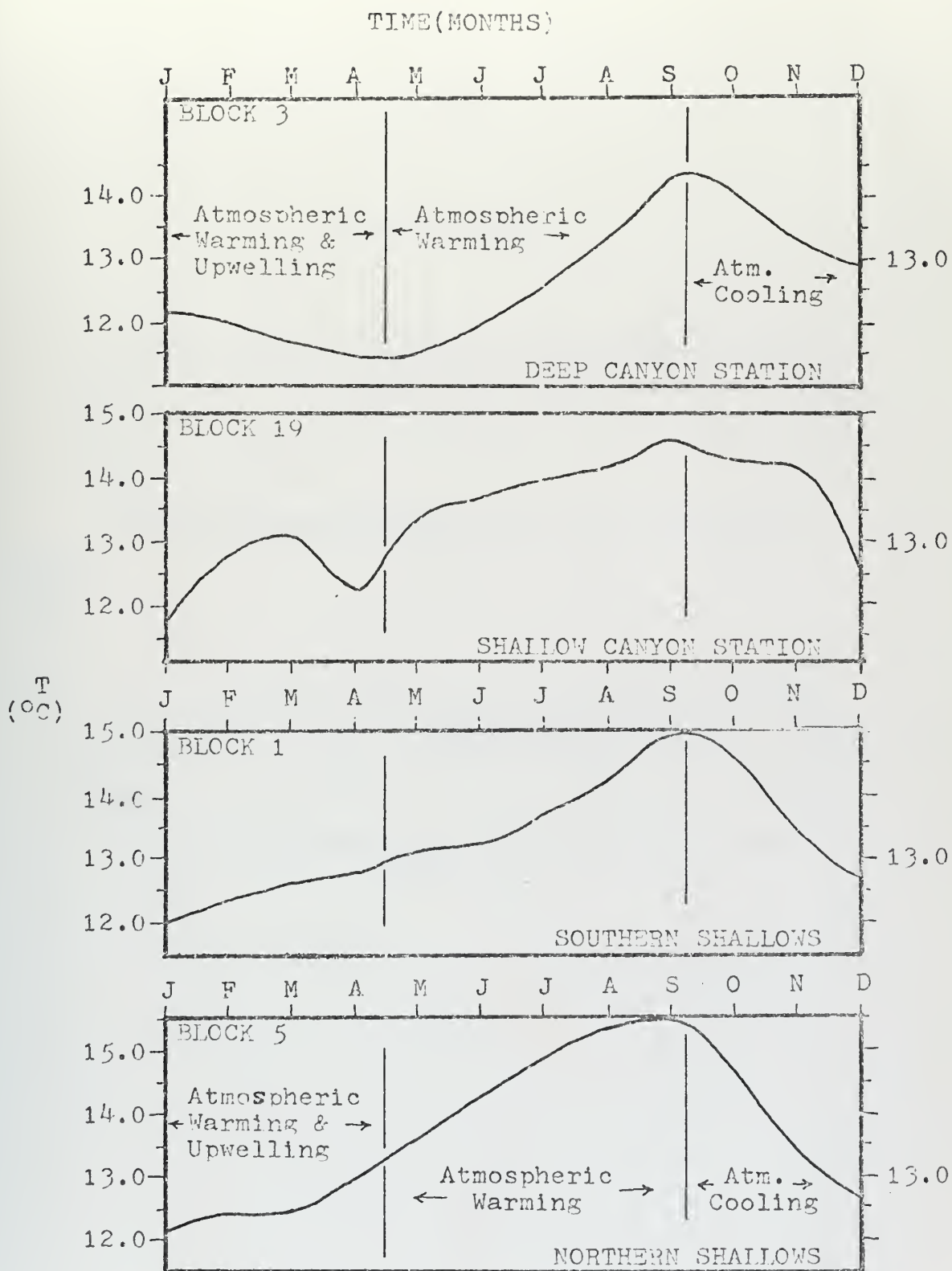


Figure 13. The Annual Cycles of Mean Sea Surface Temperature in Very Shallow Regions of the Bay.



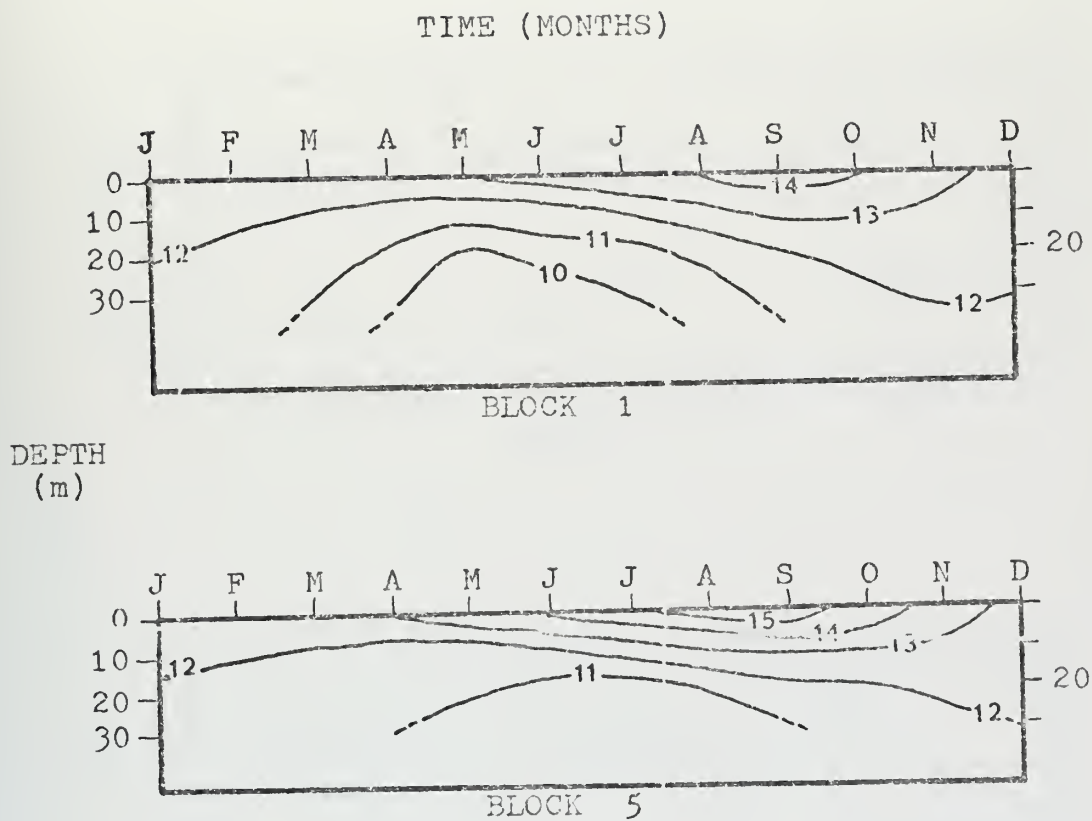
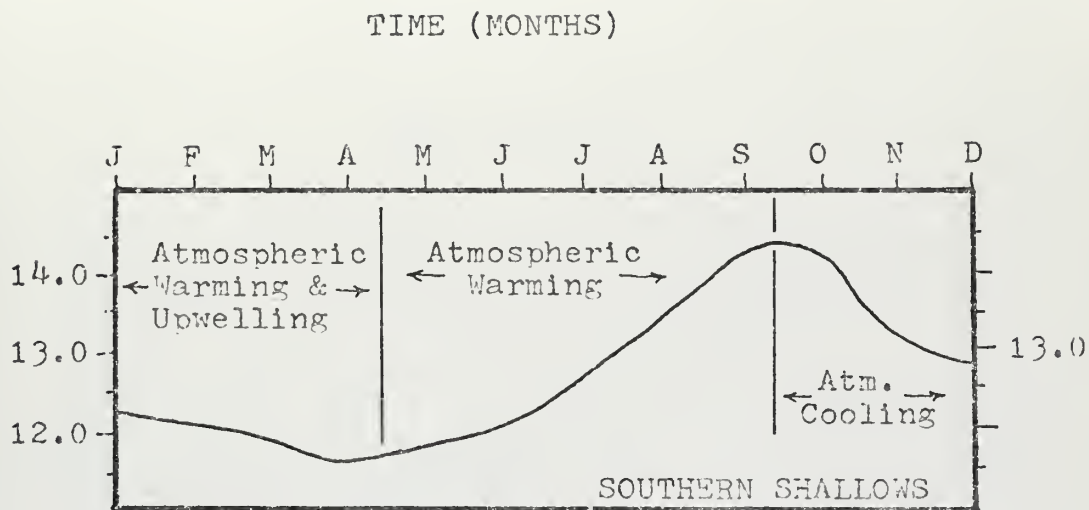


Figure 14. The Annual Mean Temperature Cycles at Blocks 1 and 5.

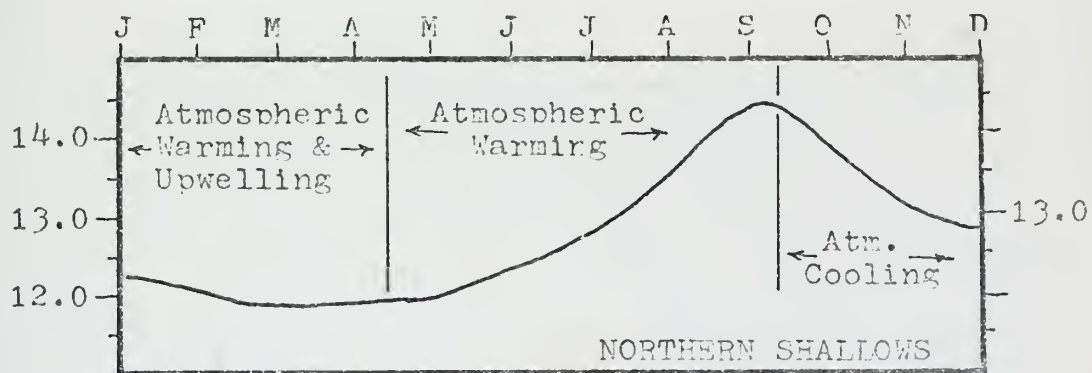






BLOCK 2

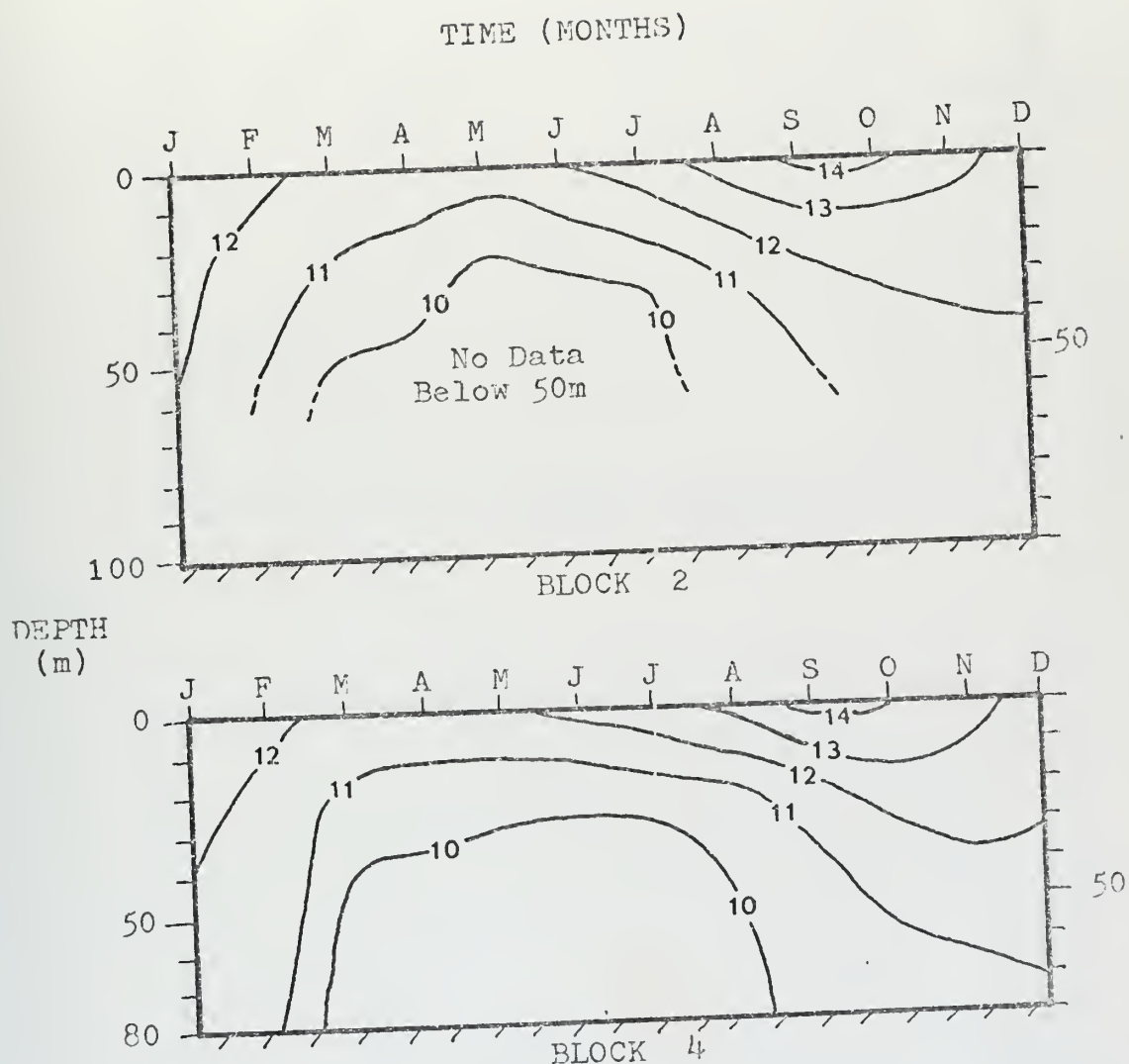
$T$   
( $^{\circ}\text{C}$ )



BLOCK 4

Figure 15. The Annual Cycles of Mean Sea Surface Temperature in Relatively Deeper Regions of the Shallows.

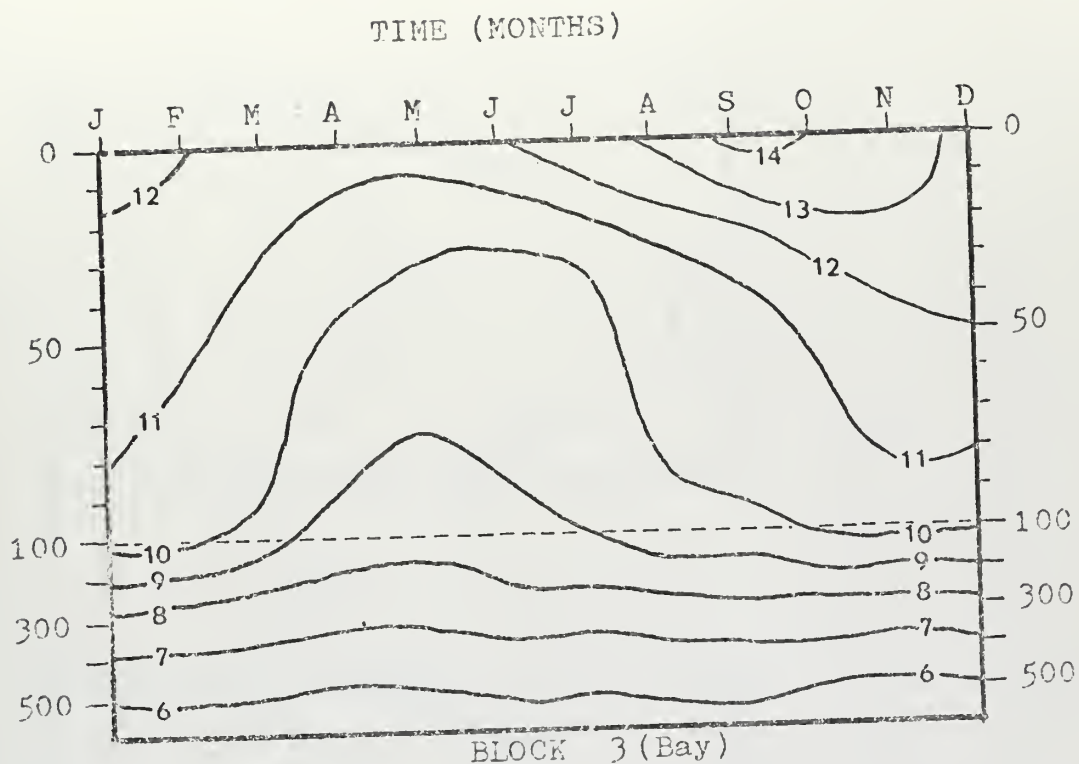




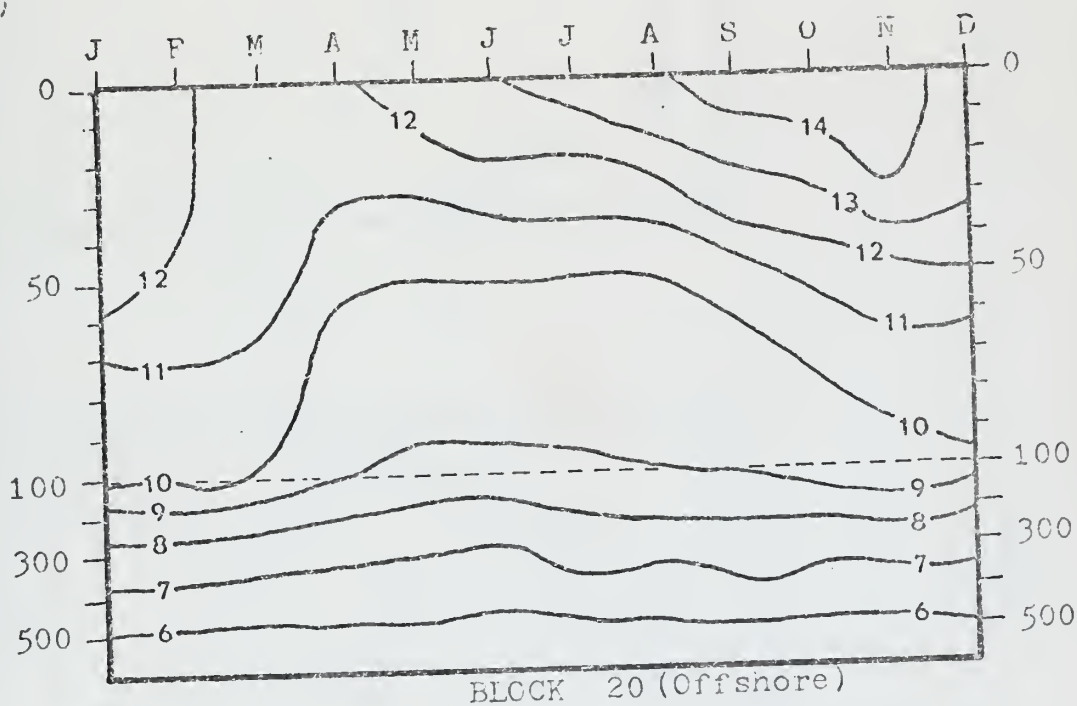
NOTE: The steep slopes of the 10°C and 11°C isotherms at Block 4 illustrate the up-slope entry of cold waters into the region.

Figure 16. The Annual Mean Temperature Cycles at Blocks 2 and 4.





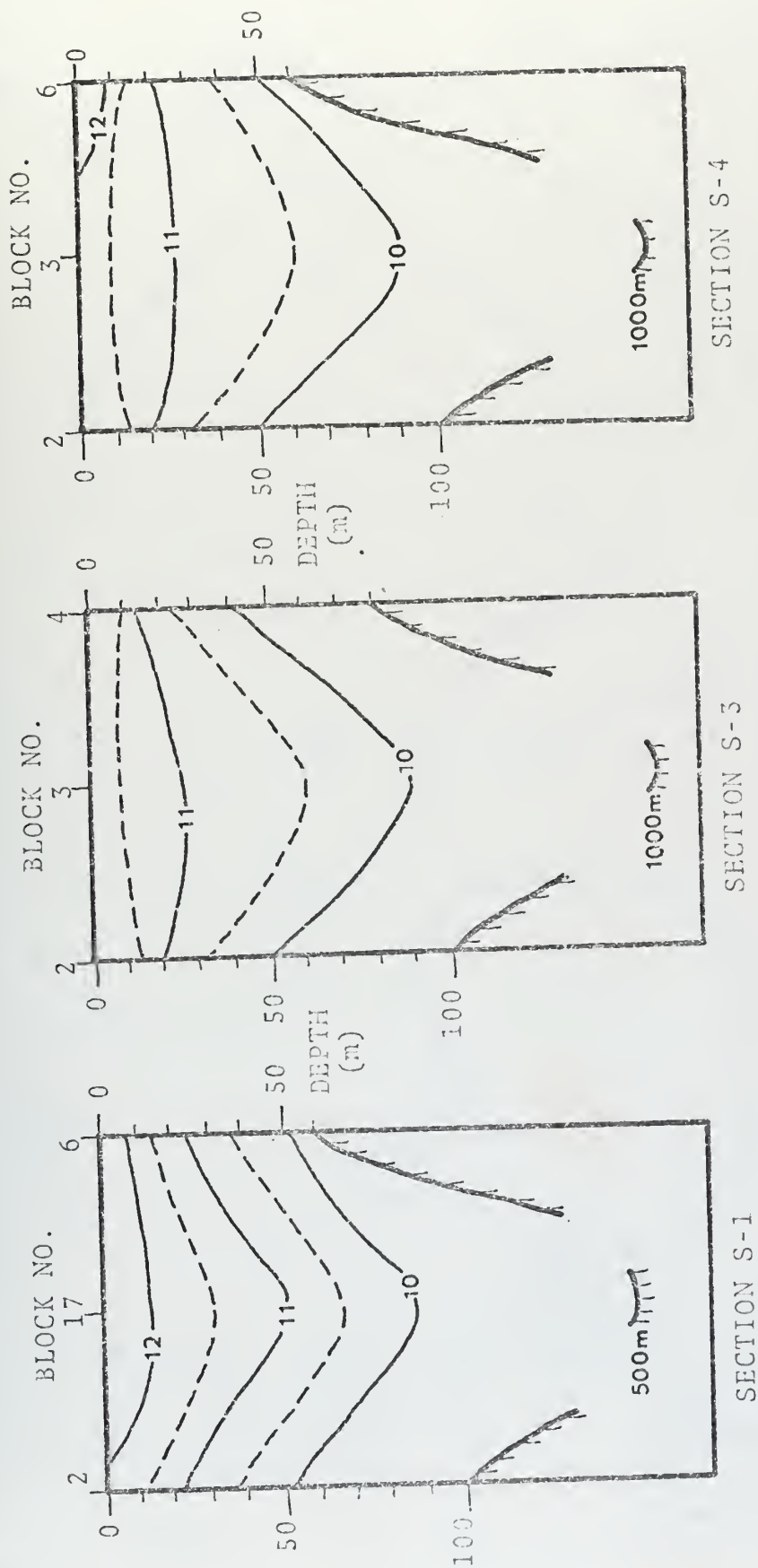
DEPTH  
(m)



NOTE: Dashed lines denote scale change.

Figure 17. Typical Annual Mean Temperature Cycles of a Canyon versus an Offshore Station.



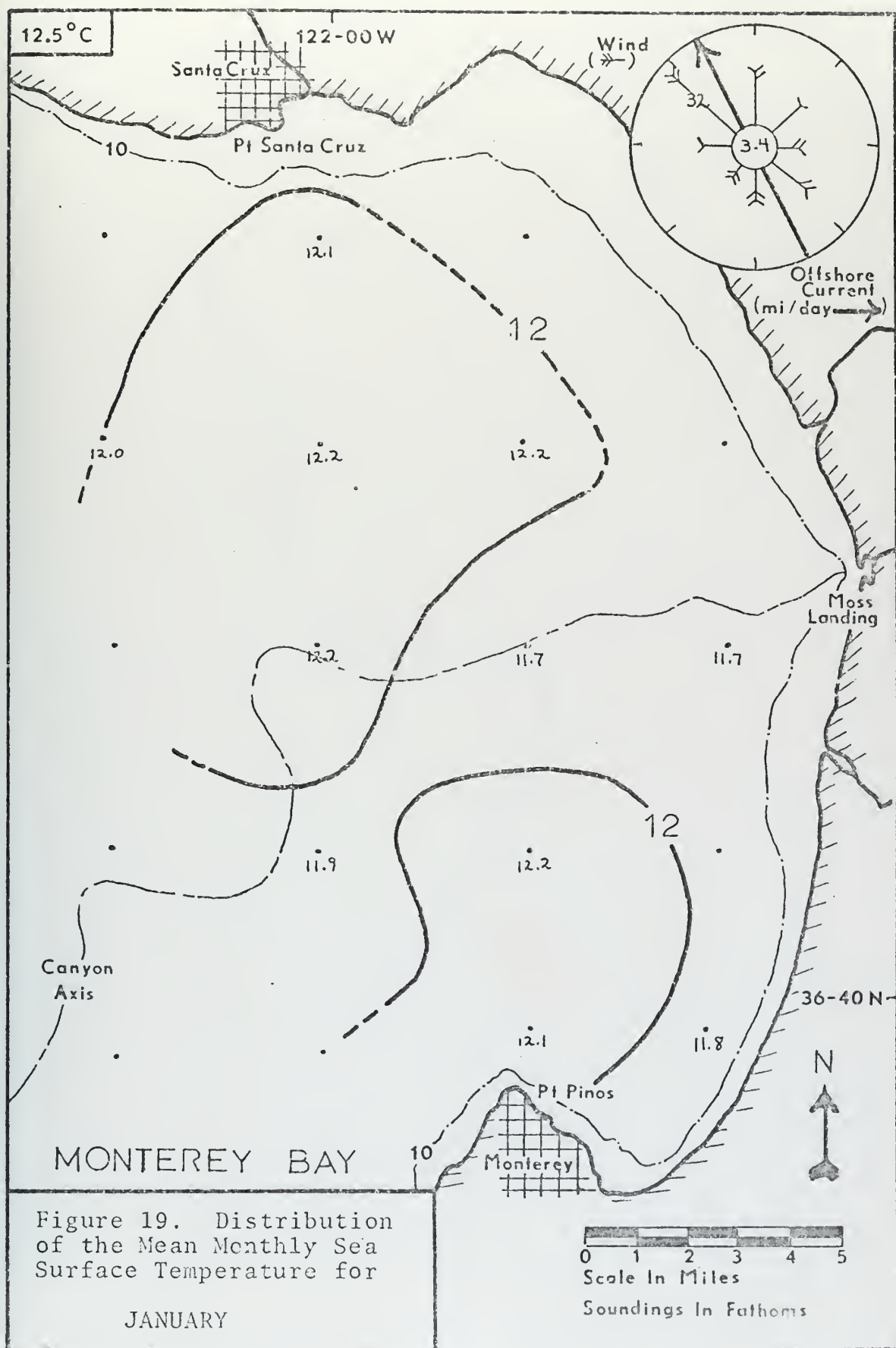


NOTE: See Figure 12 for locations of mean temperature sections.

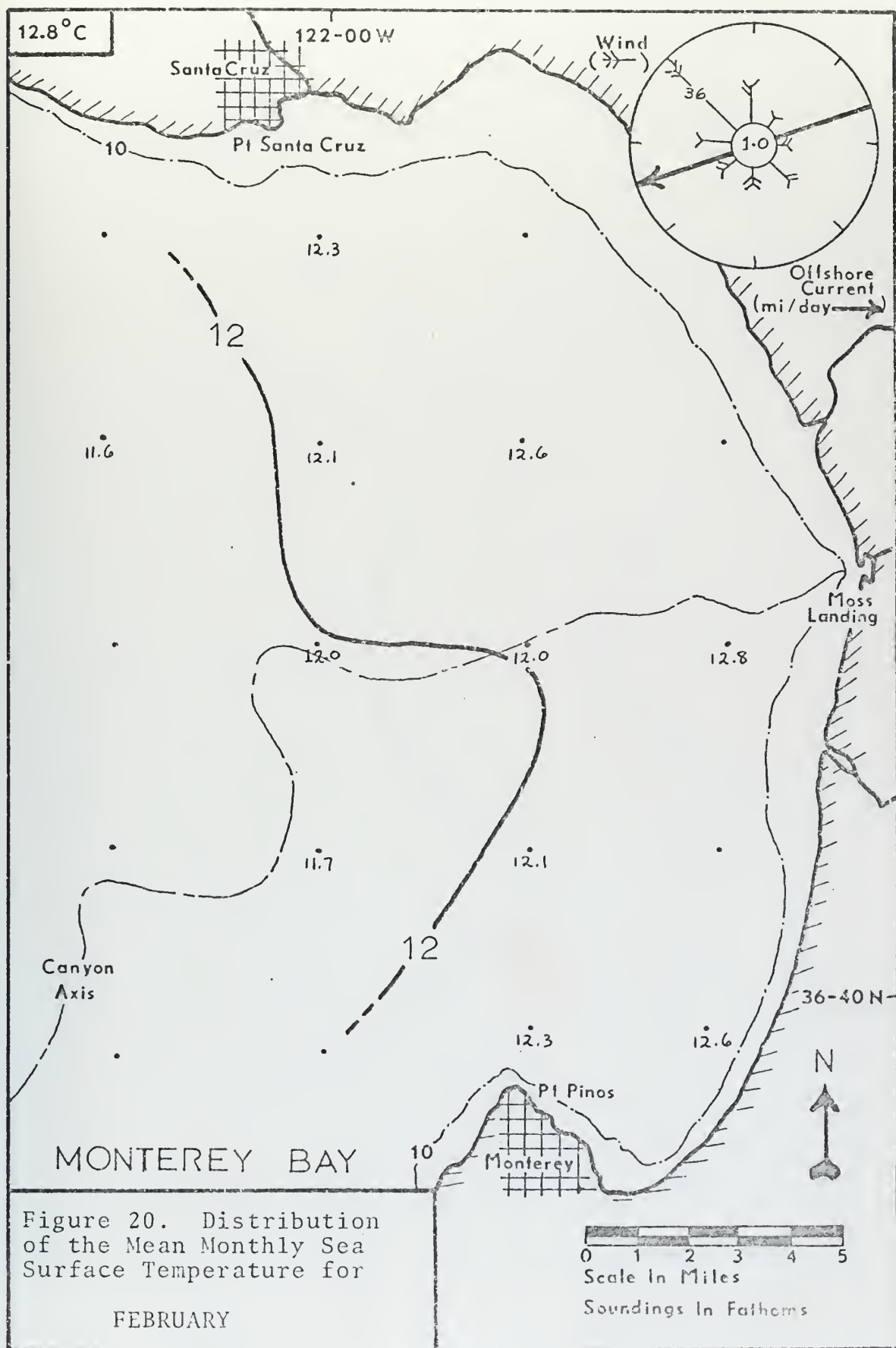
Figure 18. Dipping of the Isotherms Across the Canyon in March.



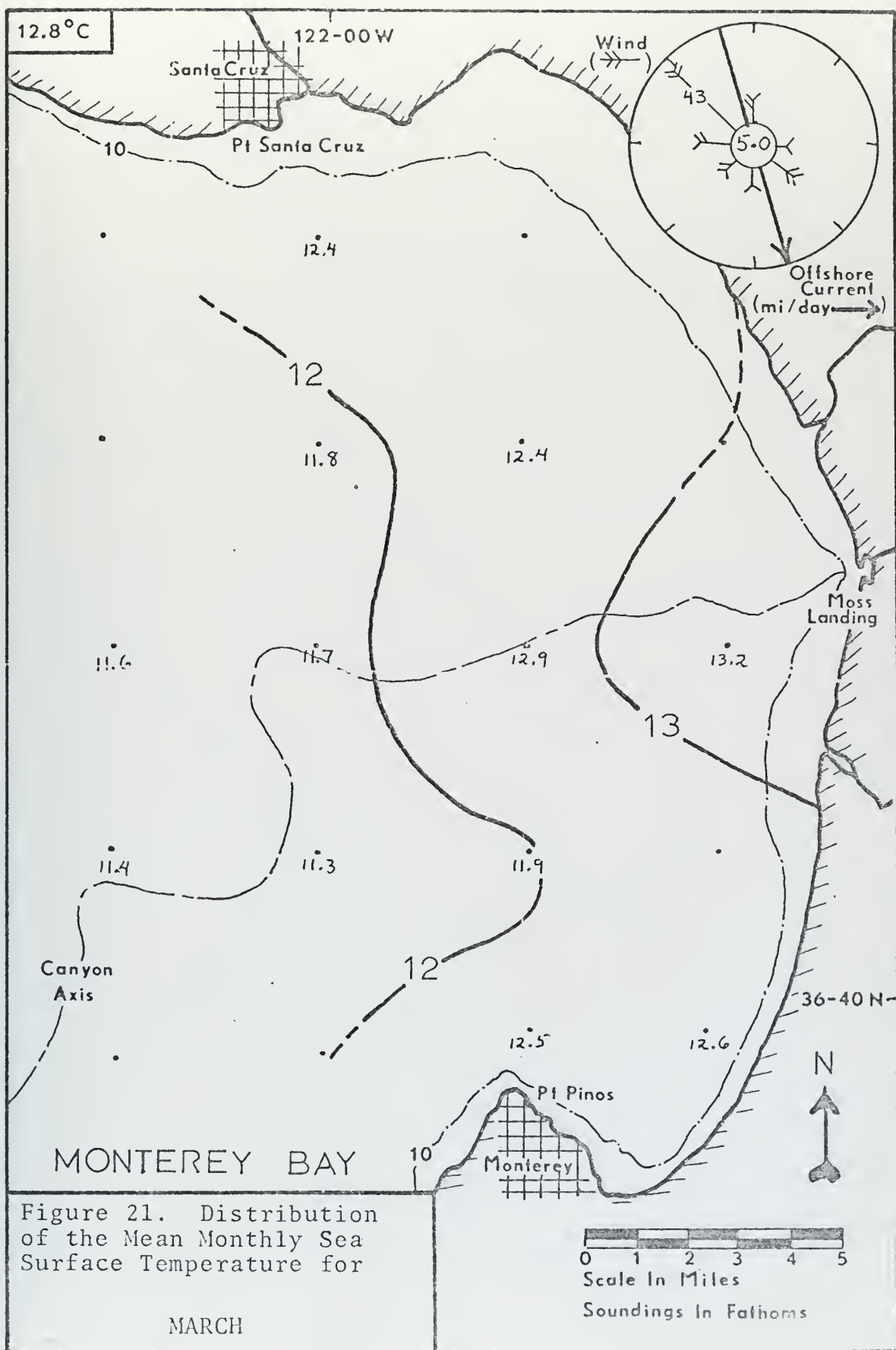




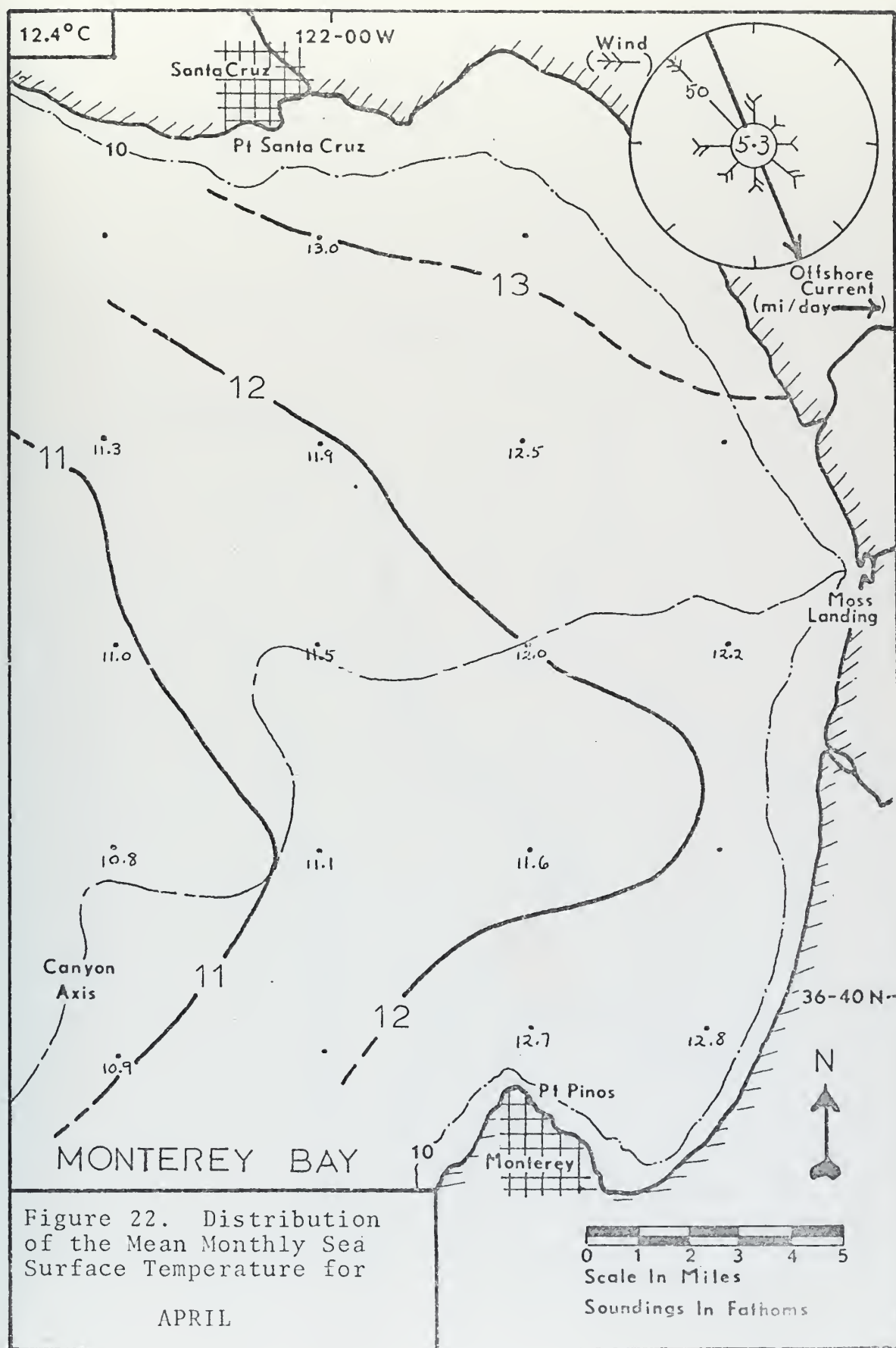






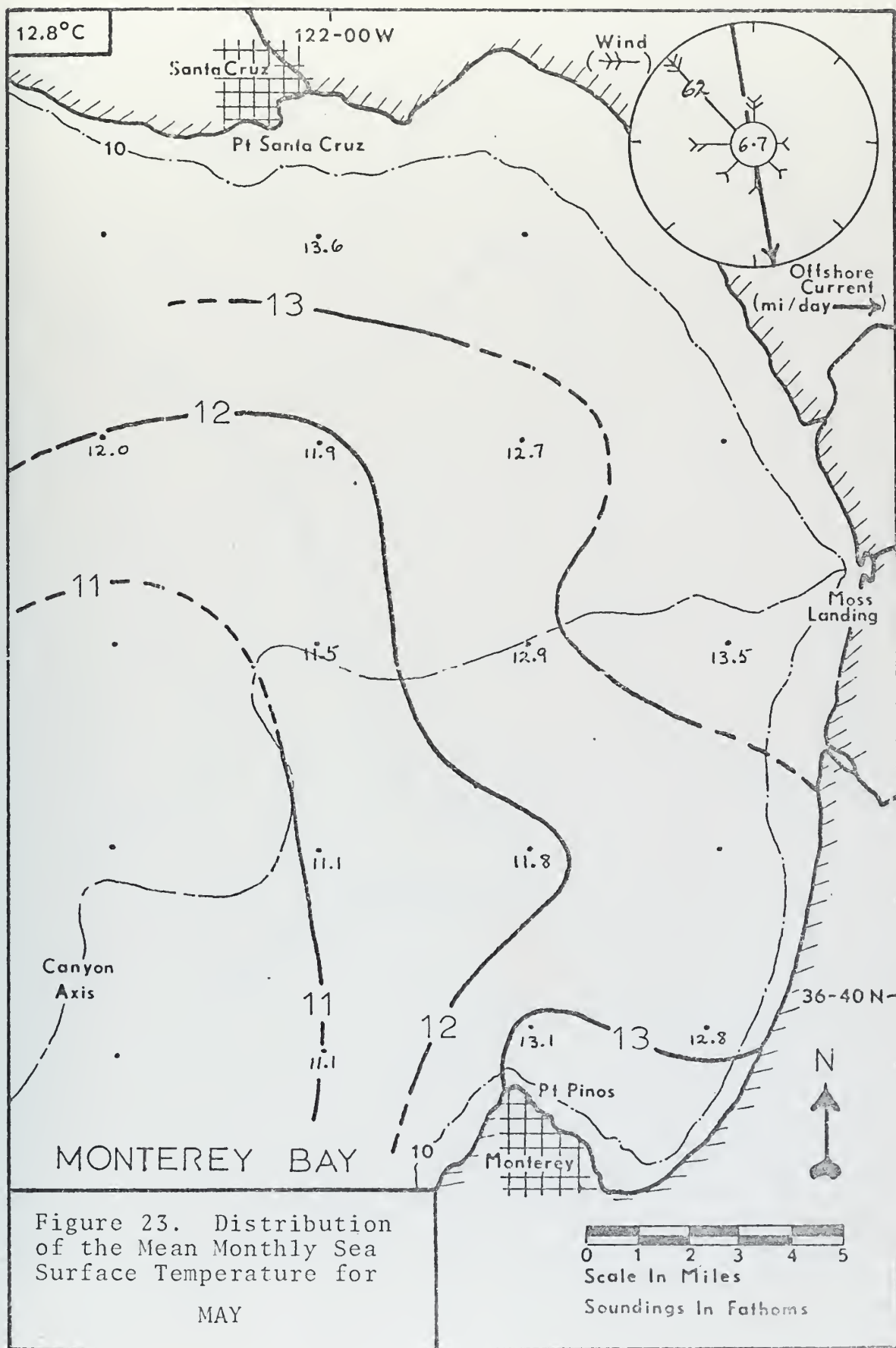




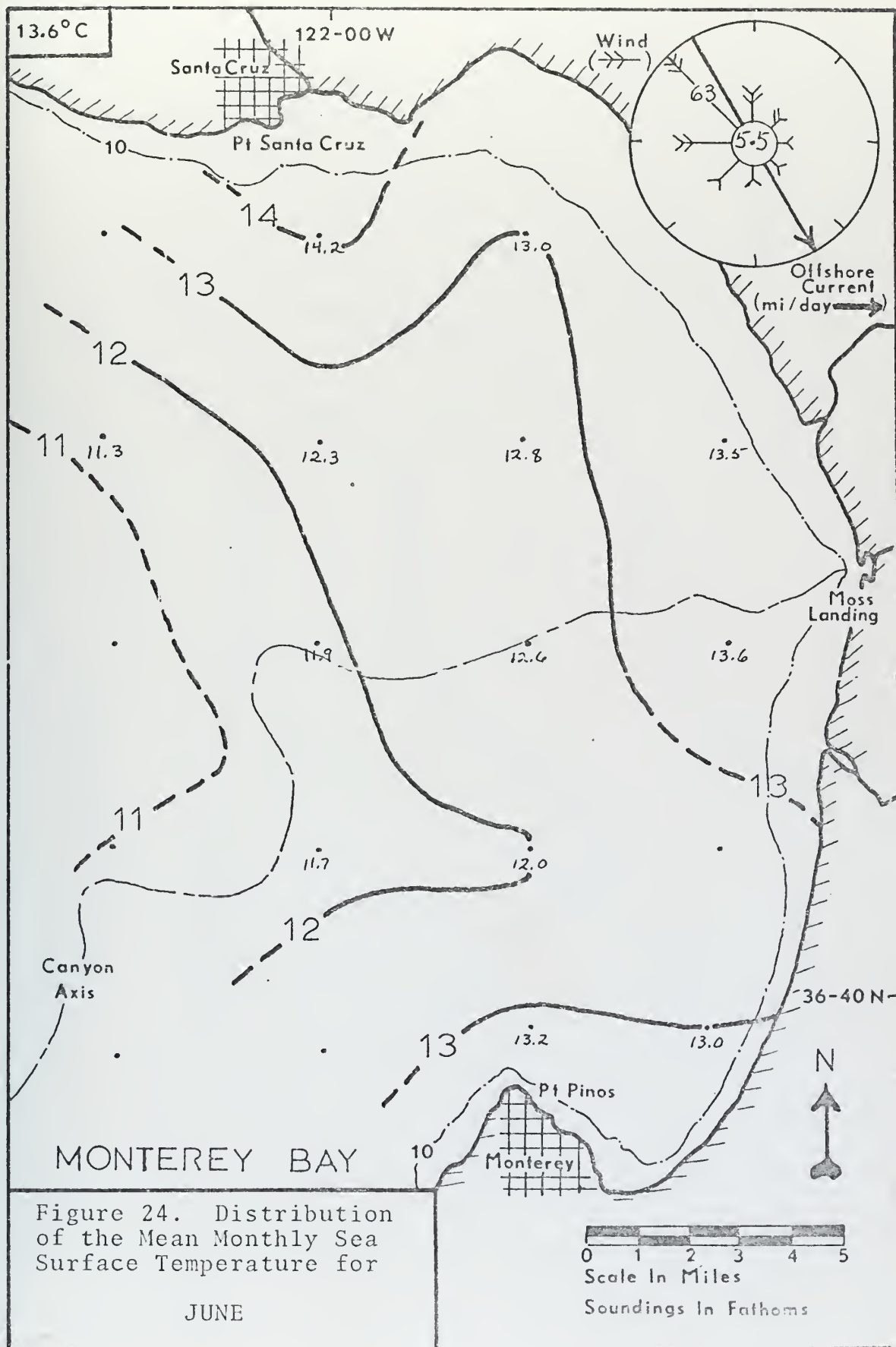




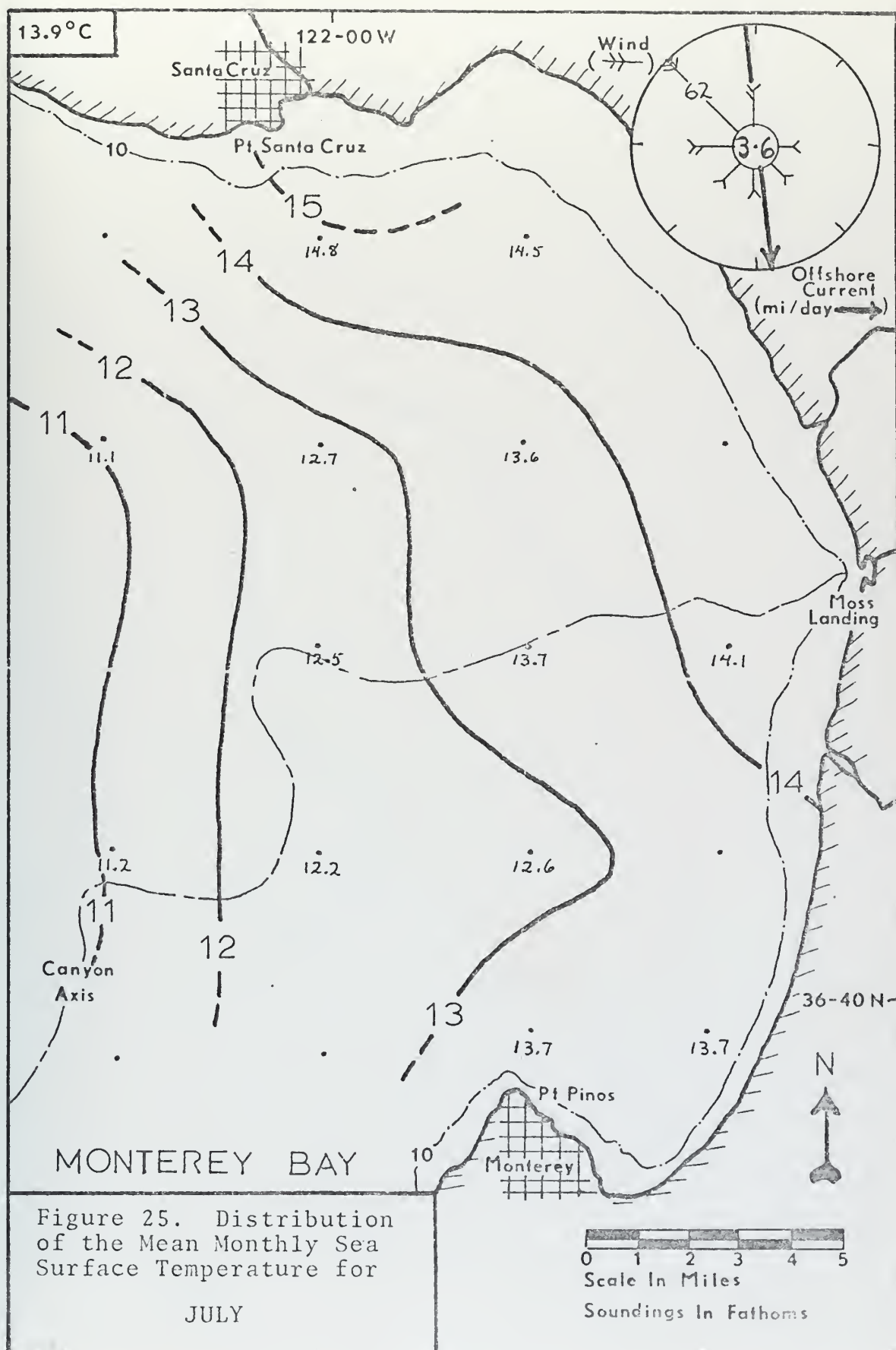














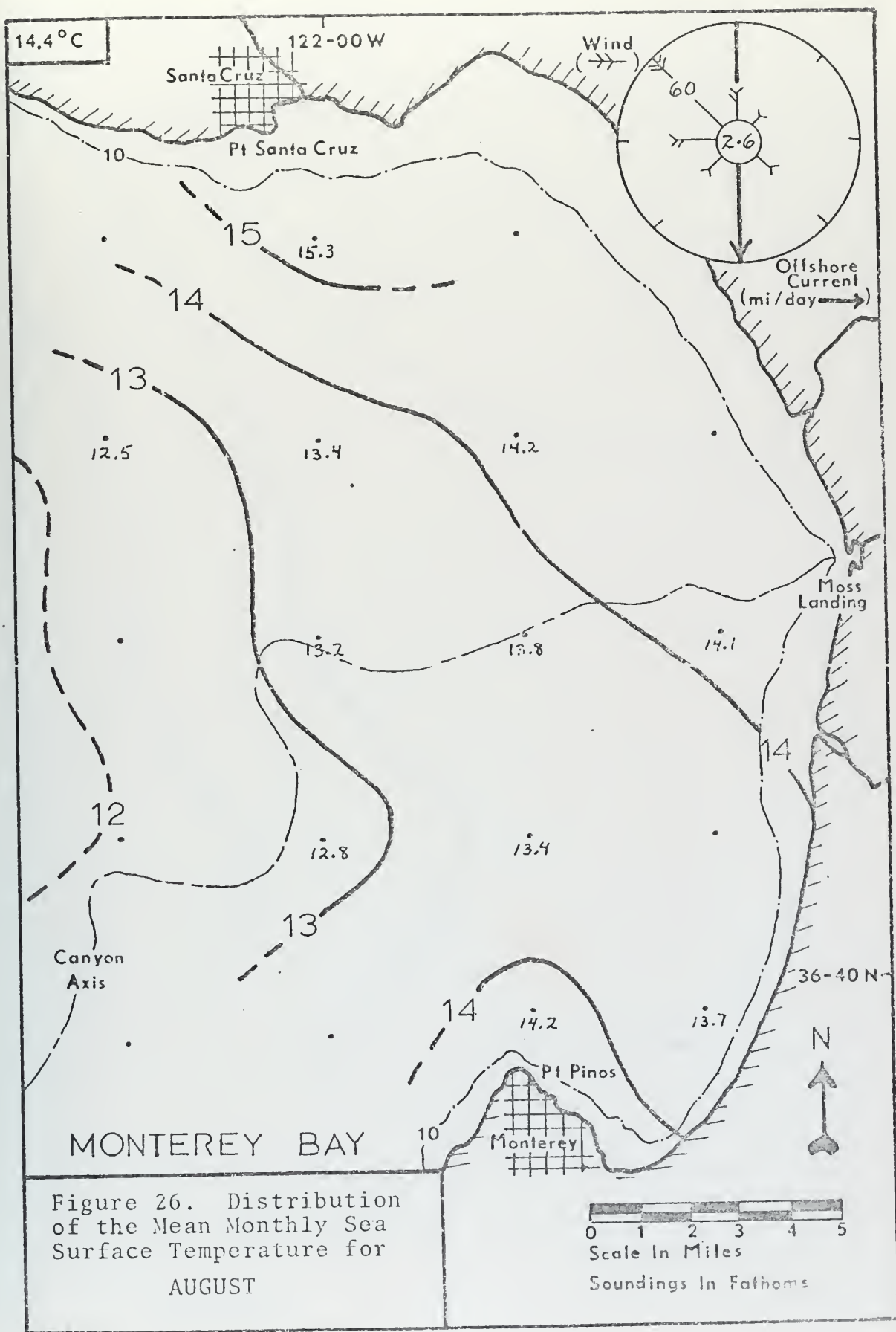
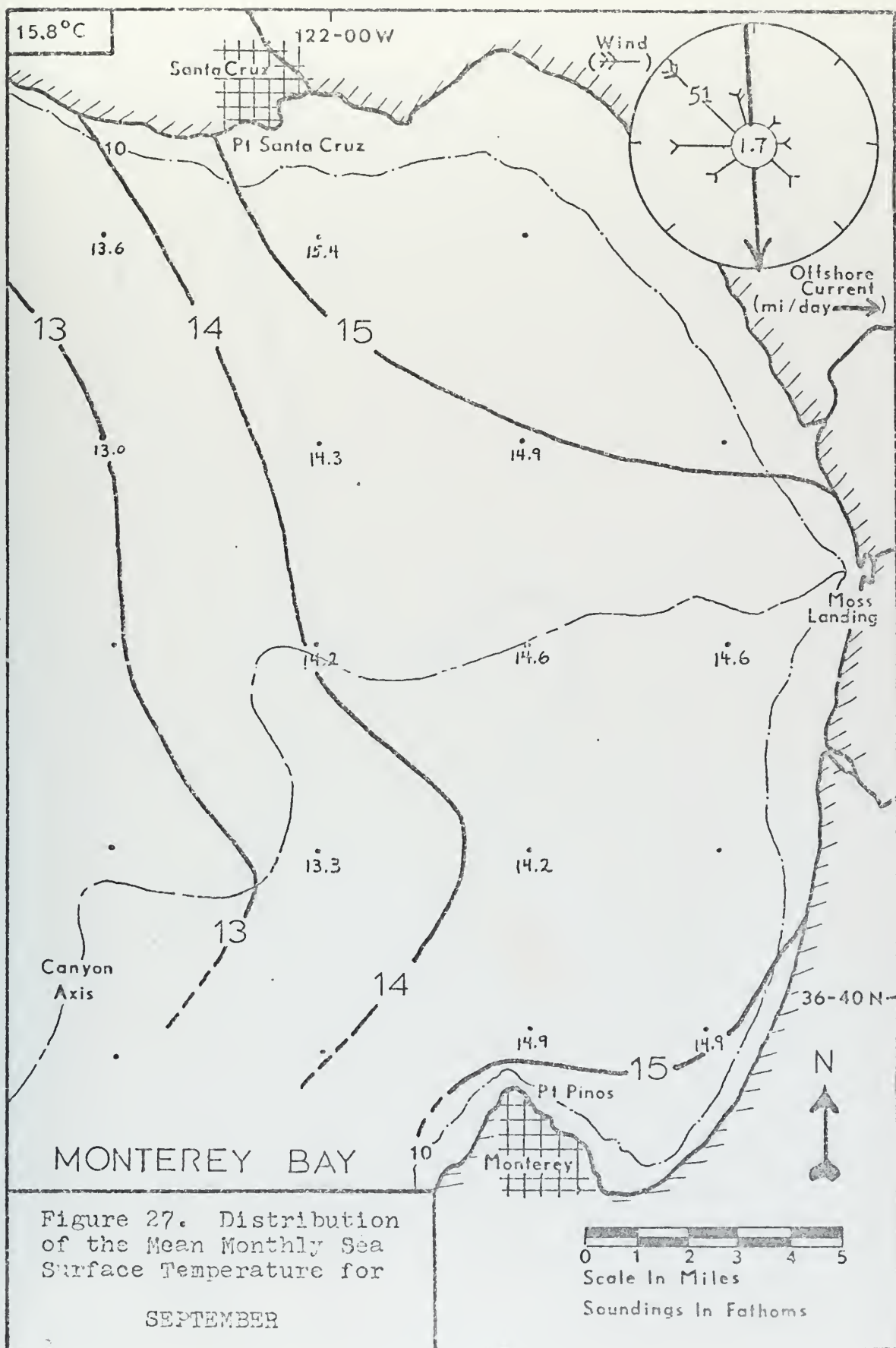


Figure 26. Distribution of the Mean Monthly Sea Surface Temperature for AUGUST

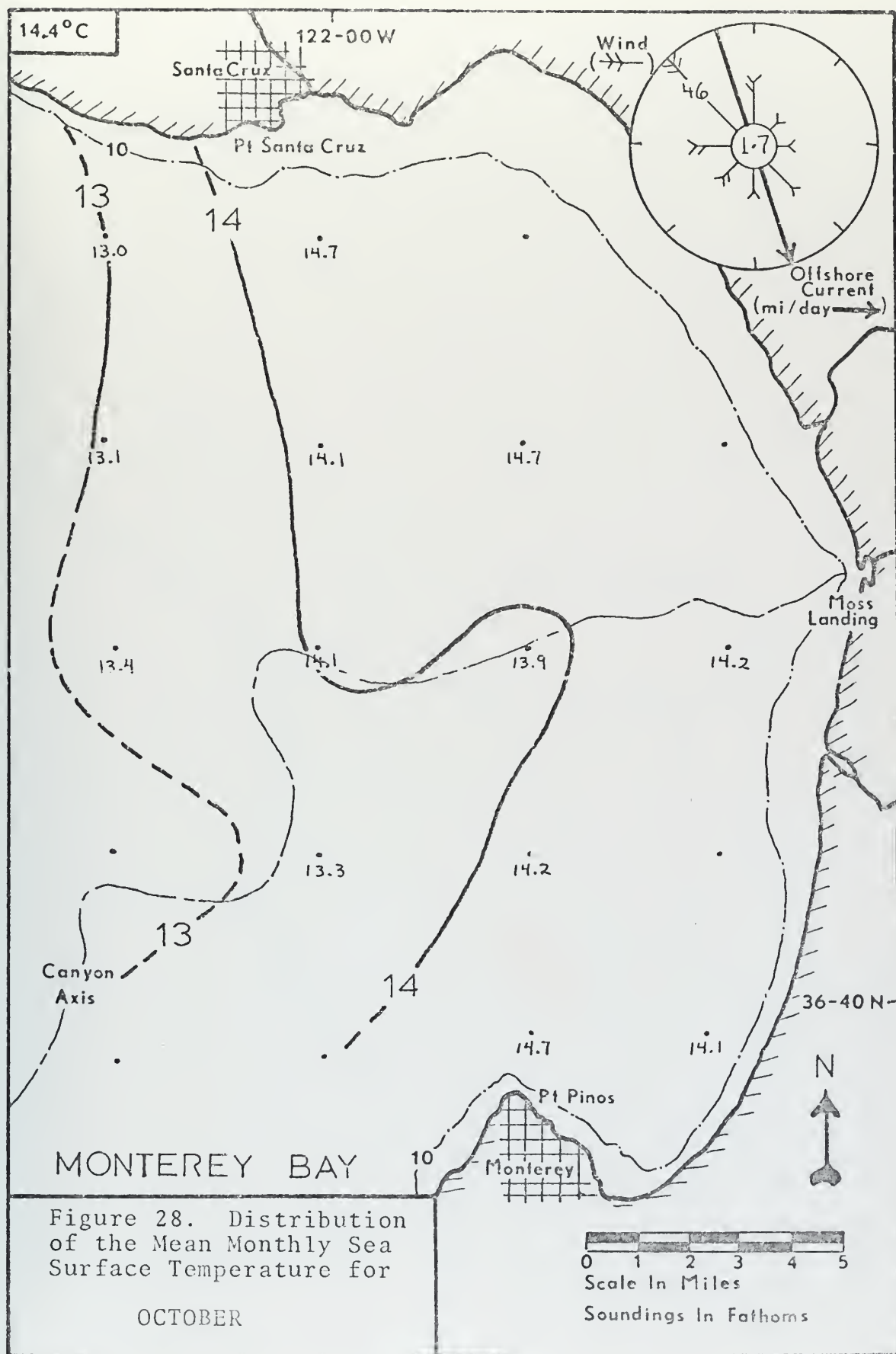














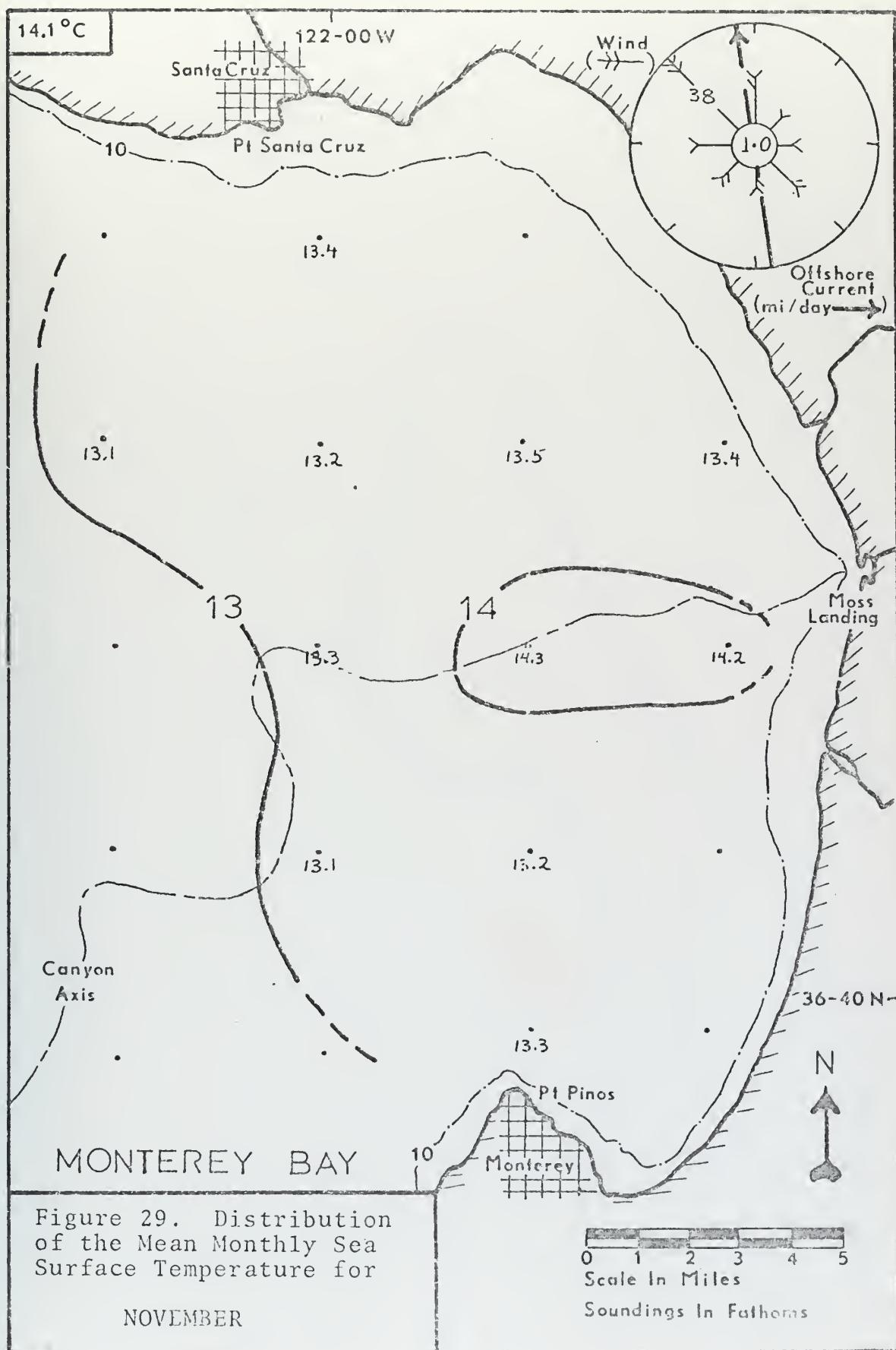
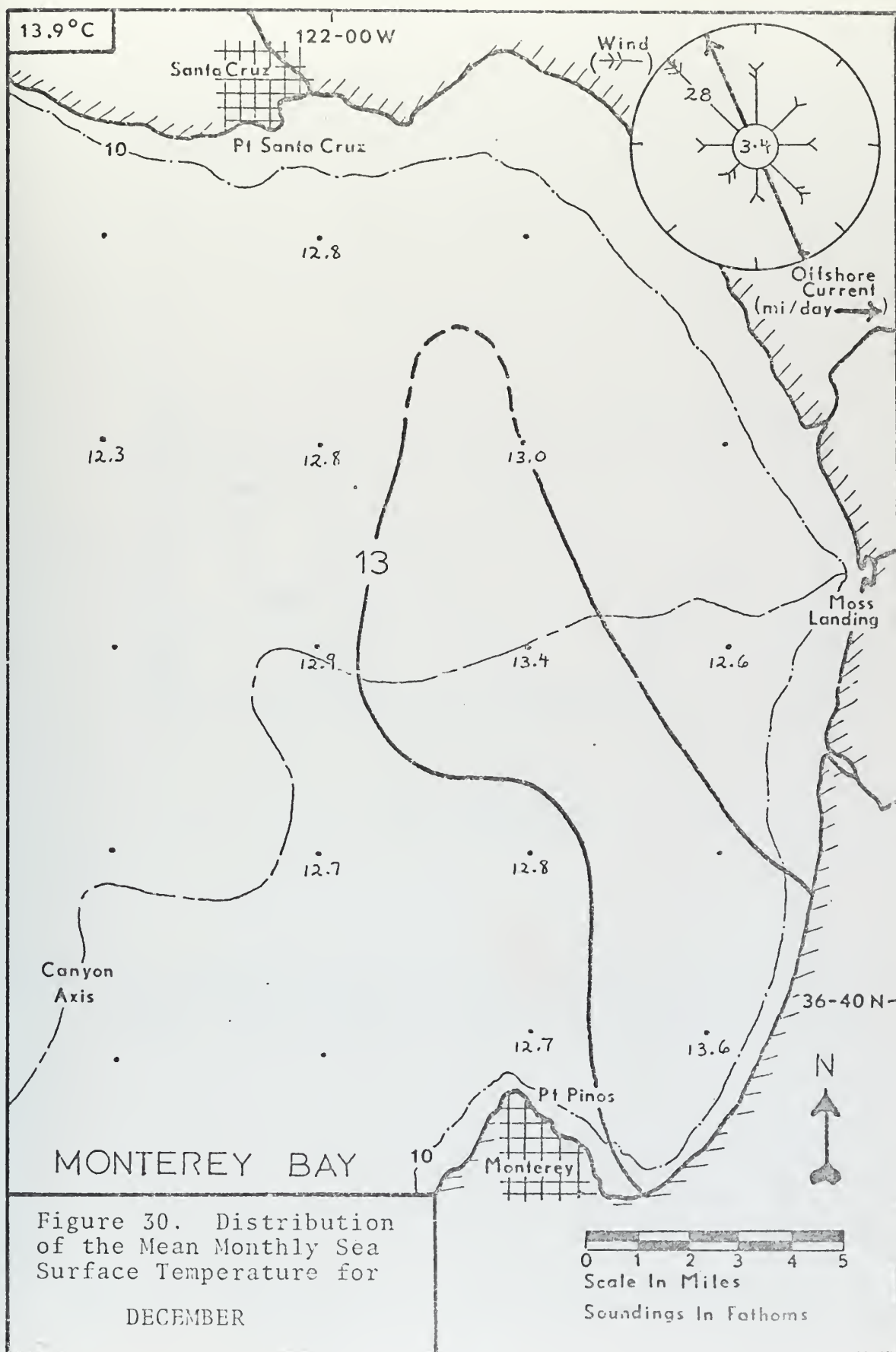


Figure 29. Distribution of the Mean Monthly Sea Surface Temperature for

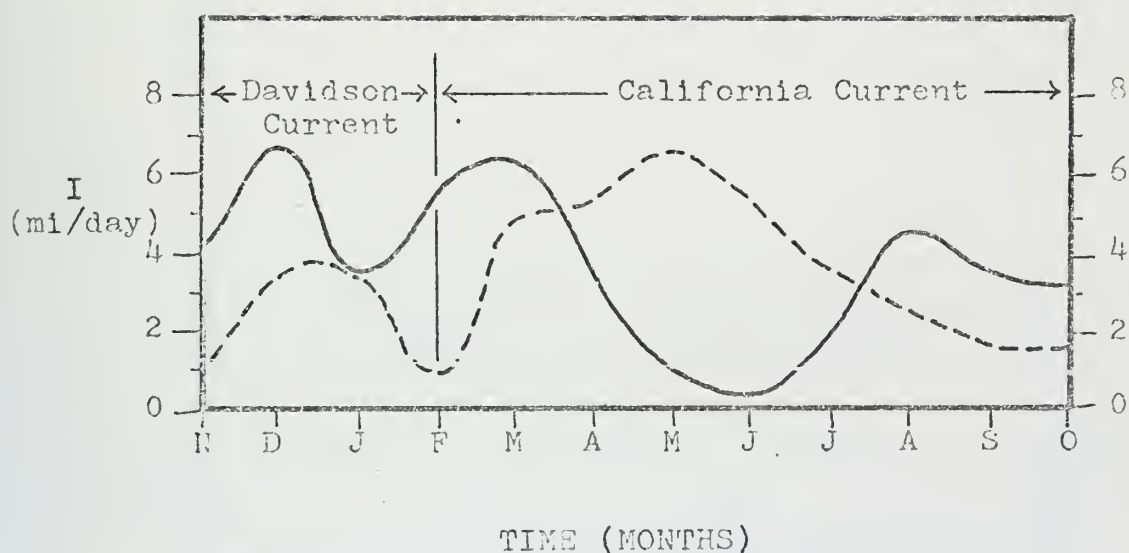
NOVEMBER







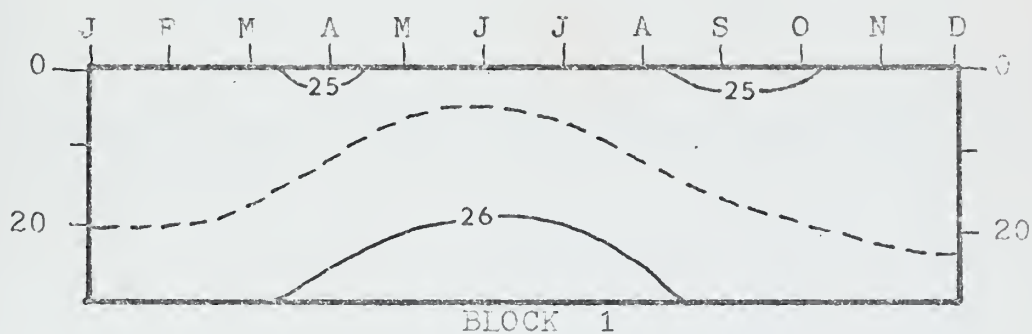
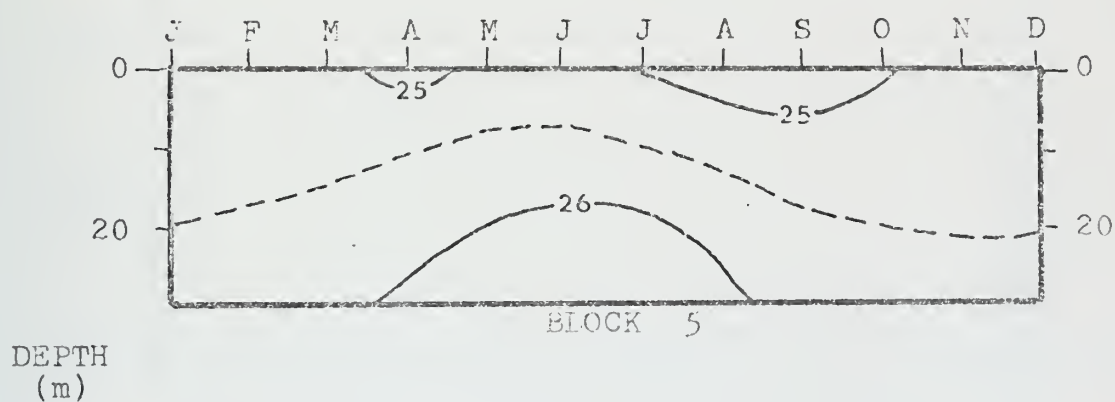
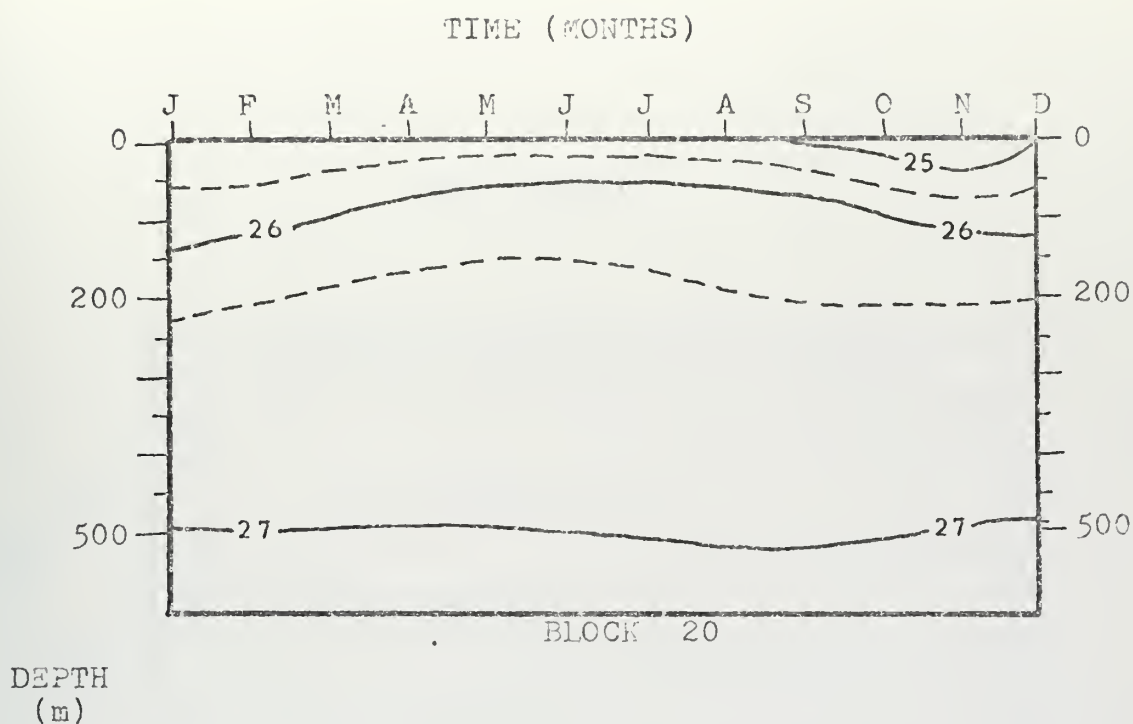




NOTE: The intensity of flow in the Bay (I) is based on contour spacing and is shown by a solid line. The dashed line denotes the mean offshore flow.

Figure 31. Intensities of Mean Flow in the Bay and Offshore.



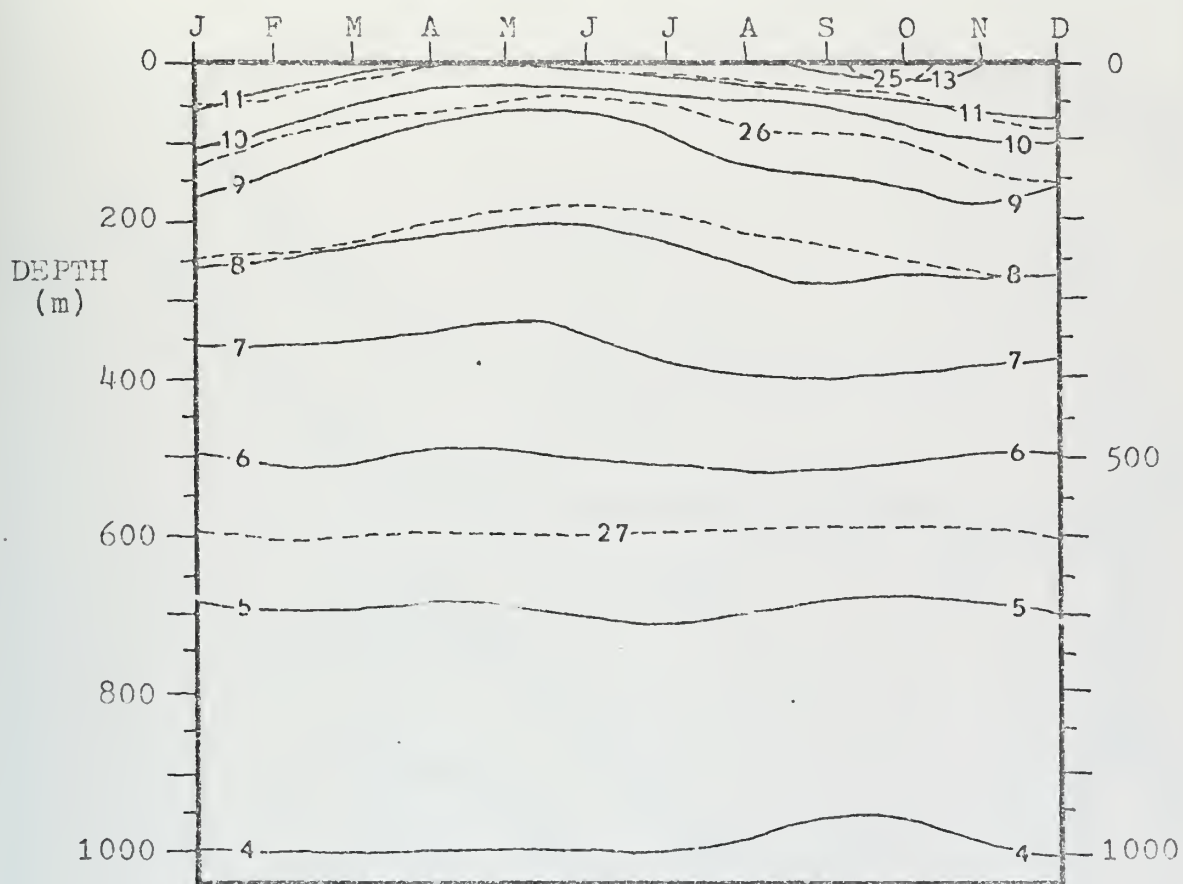


NOTE: The dashed lines denote mid-values of mean density.

Figure 32. The Annual Mean Density Cycles at Selected Blocks.



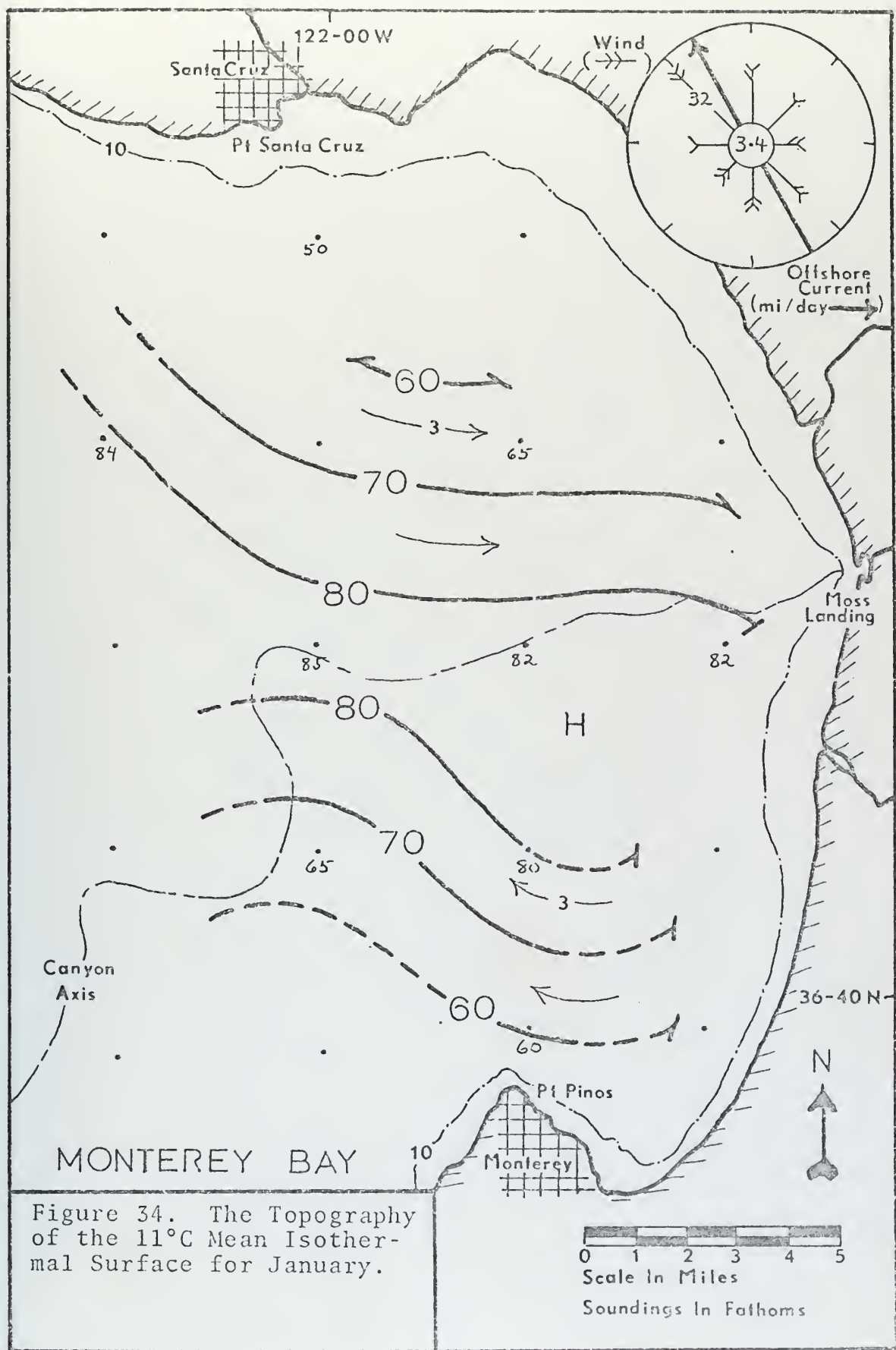
TIME (MONTHS)



NOTE: The non-labeled dashed lines denote mid-values of mean density.

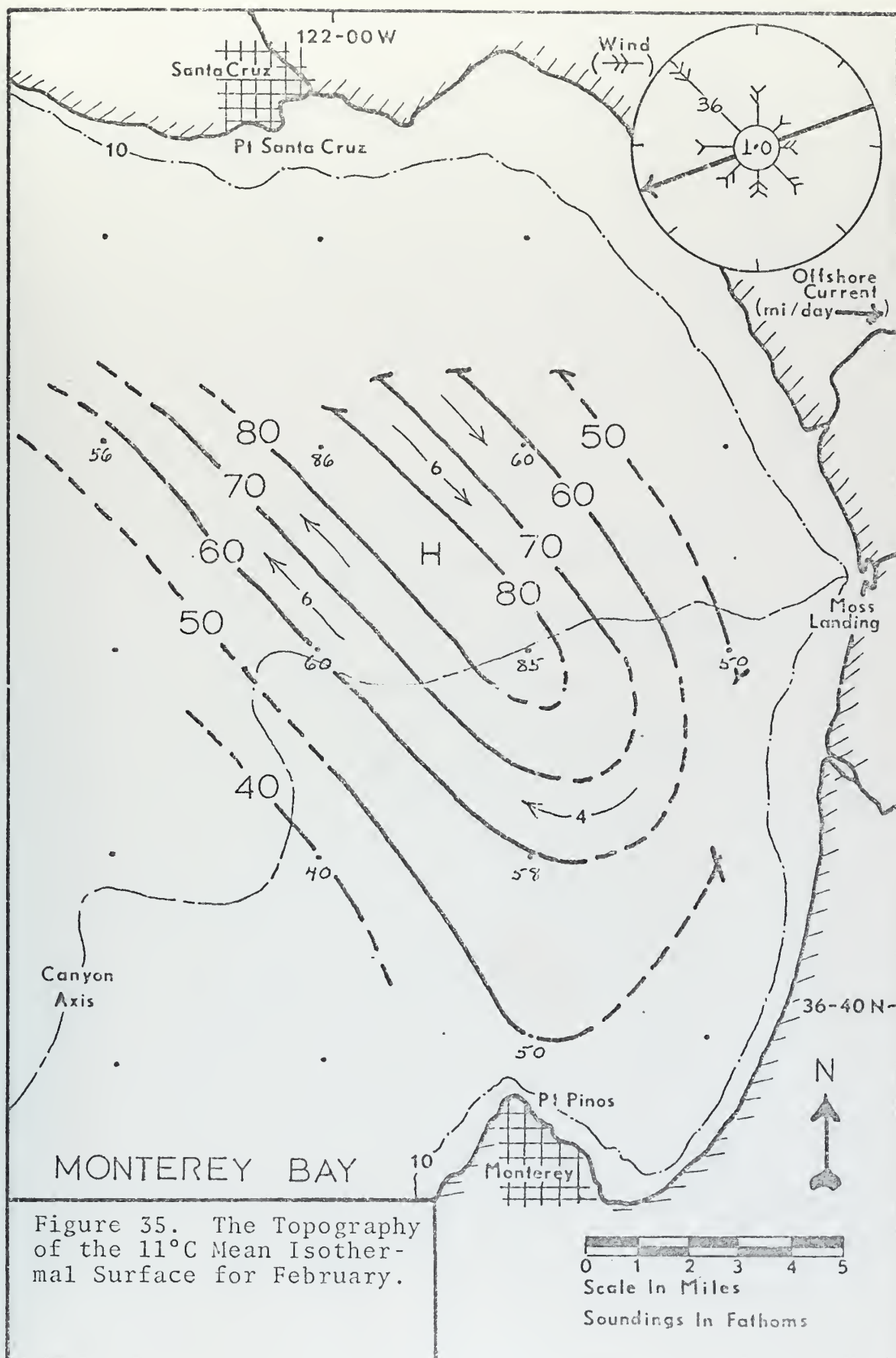
Figure 33. The Annual Mean Temperature versus Density Cycles at Block 13.



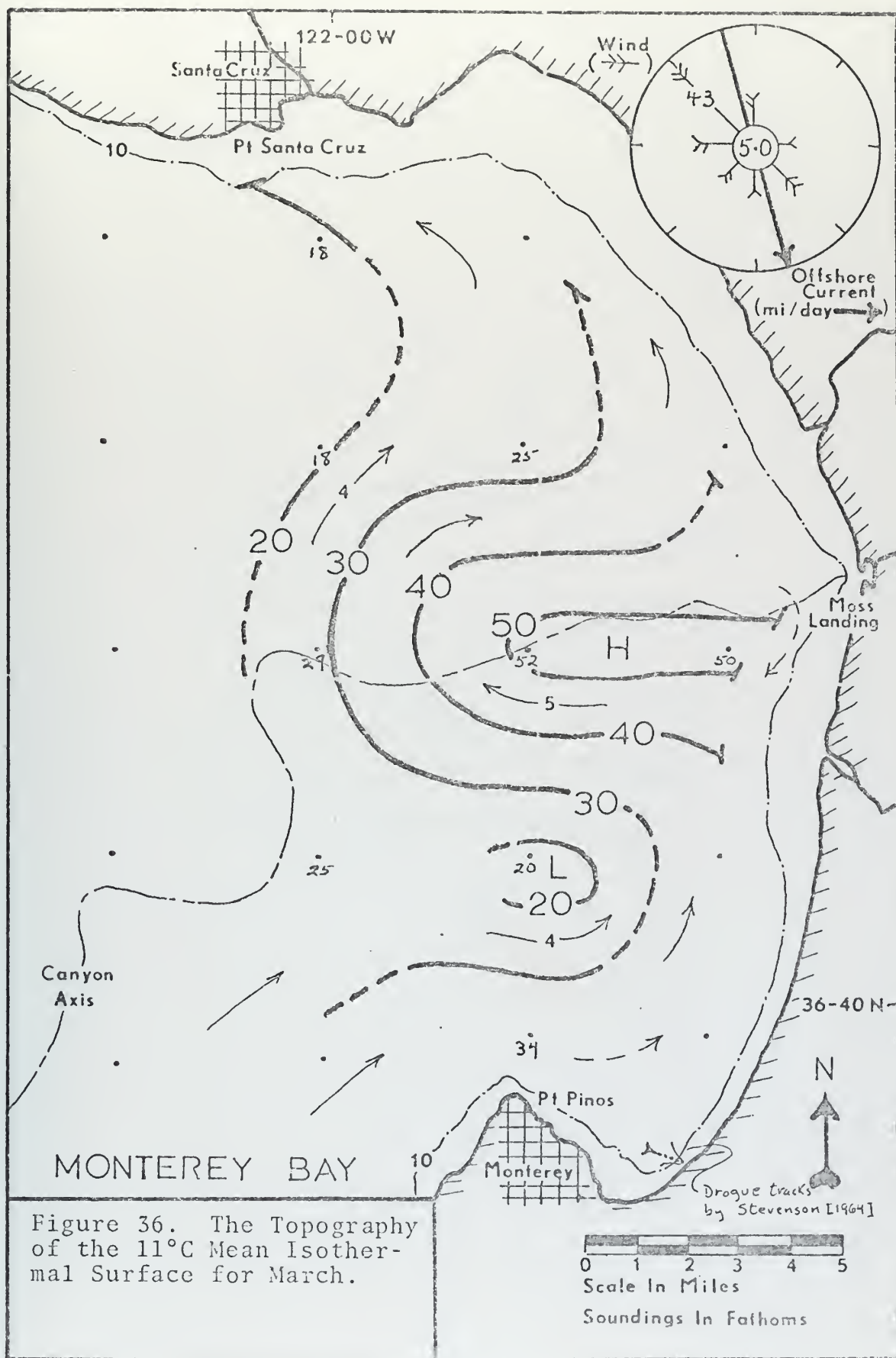




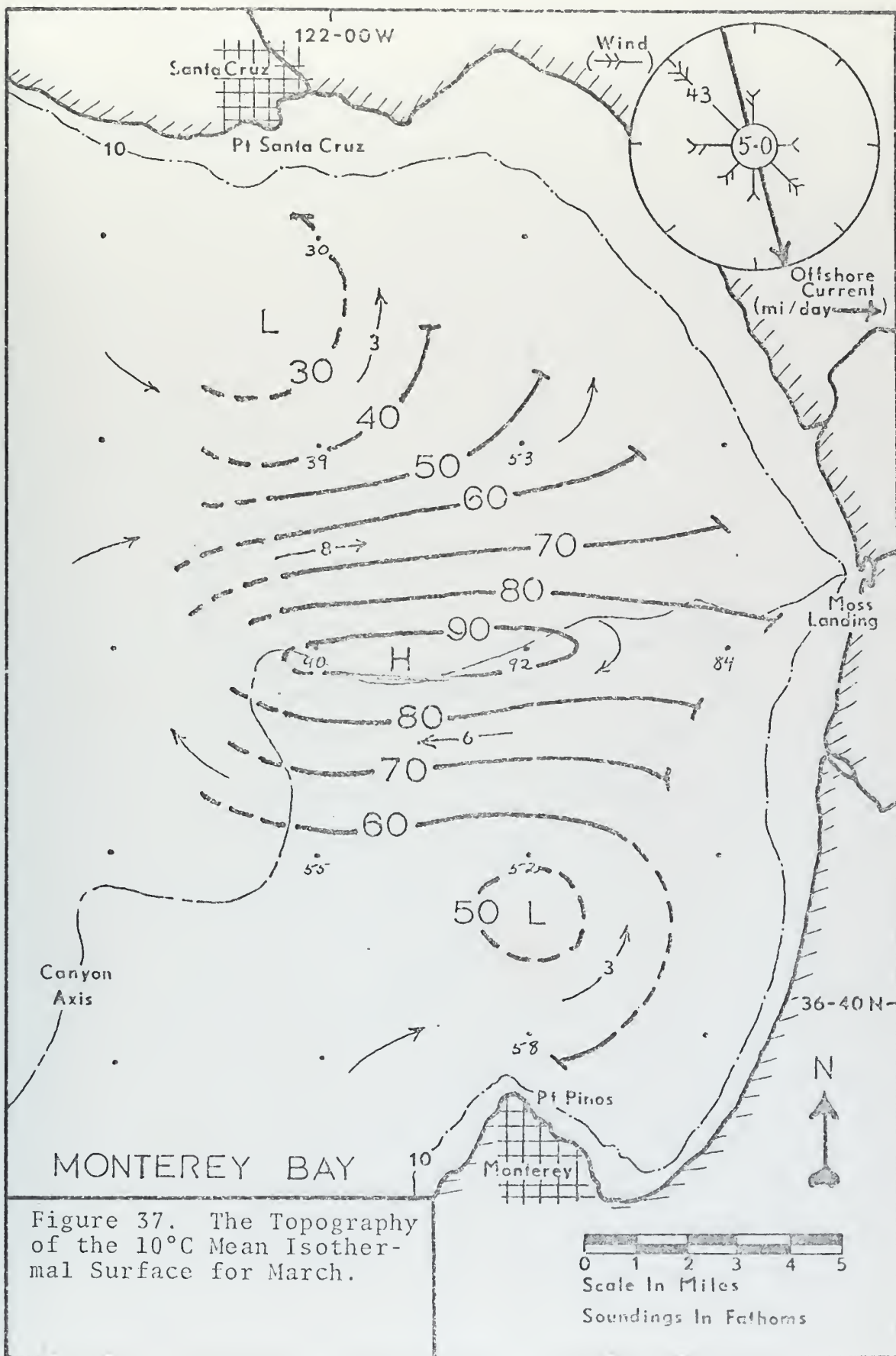






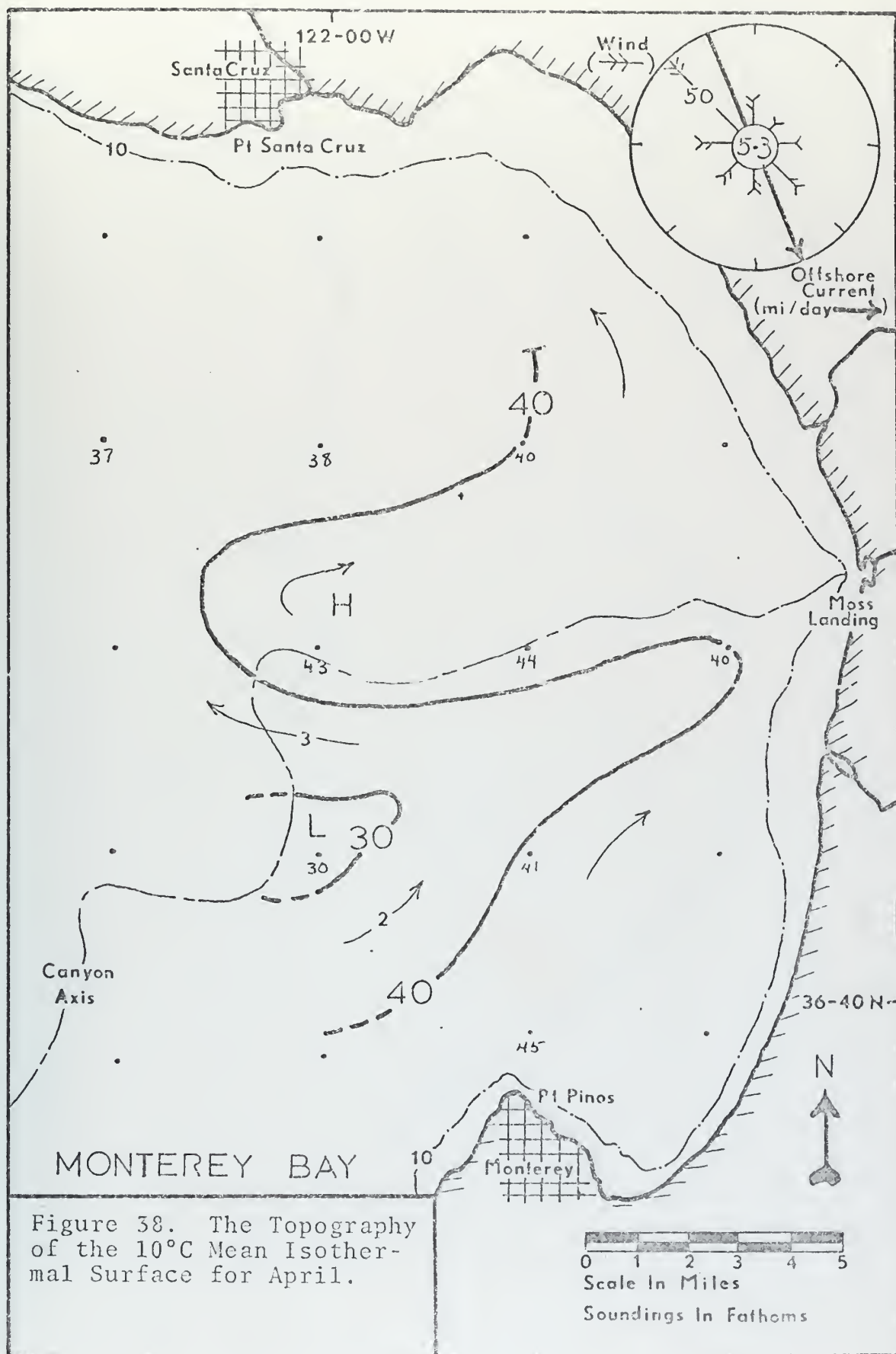






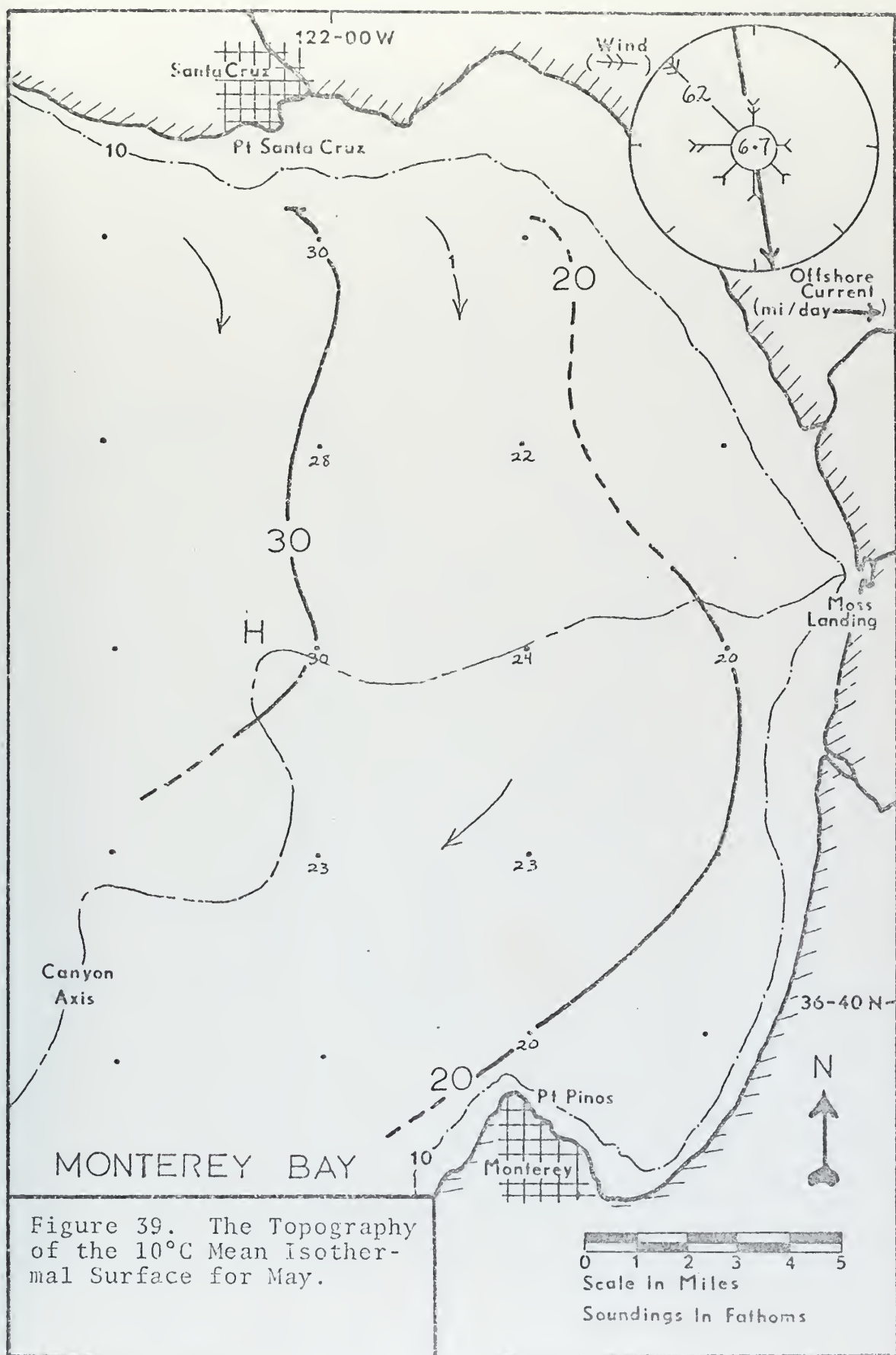




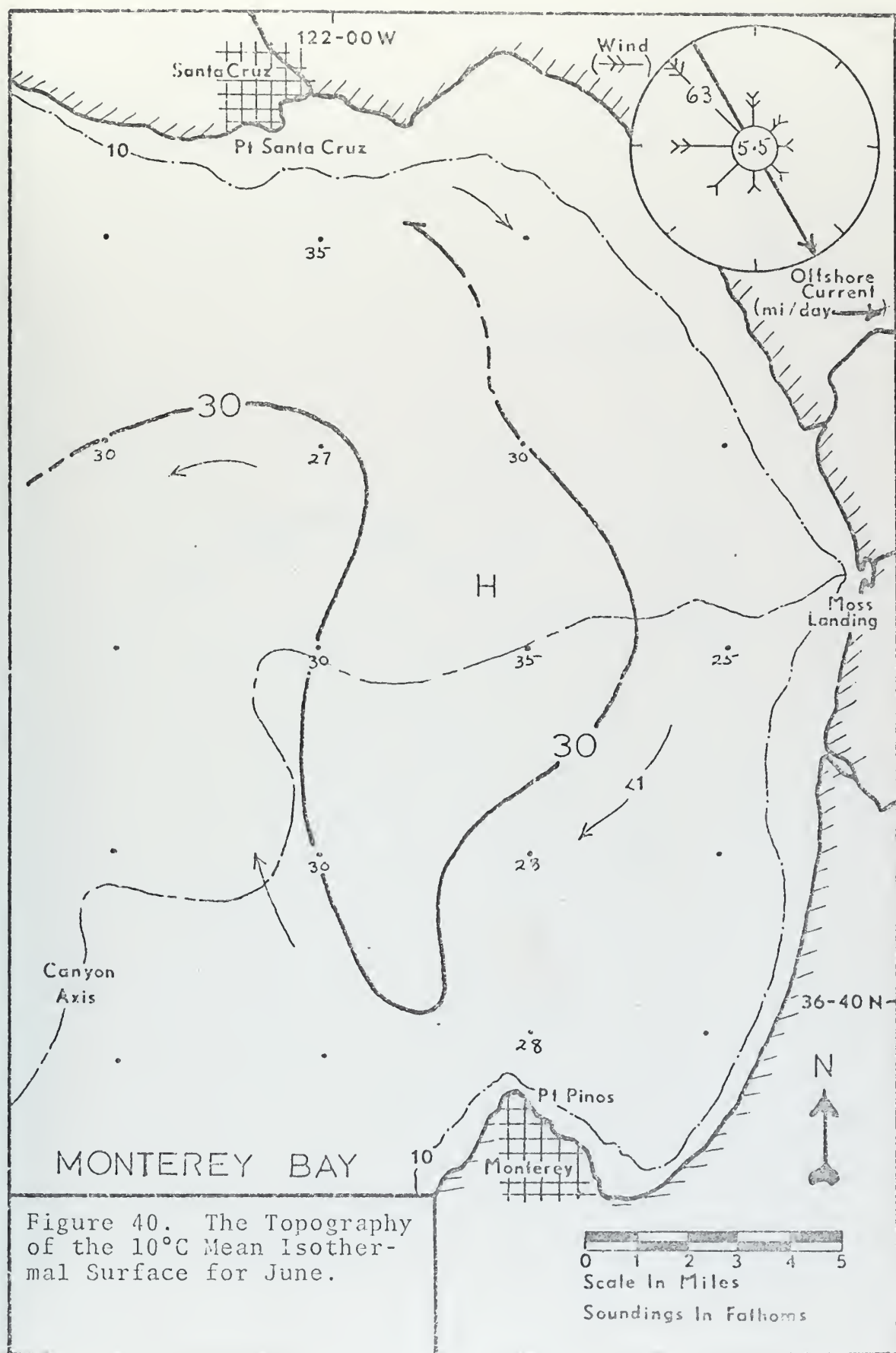














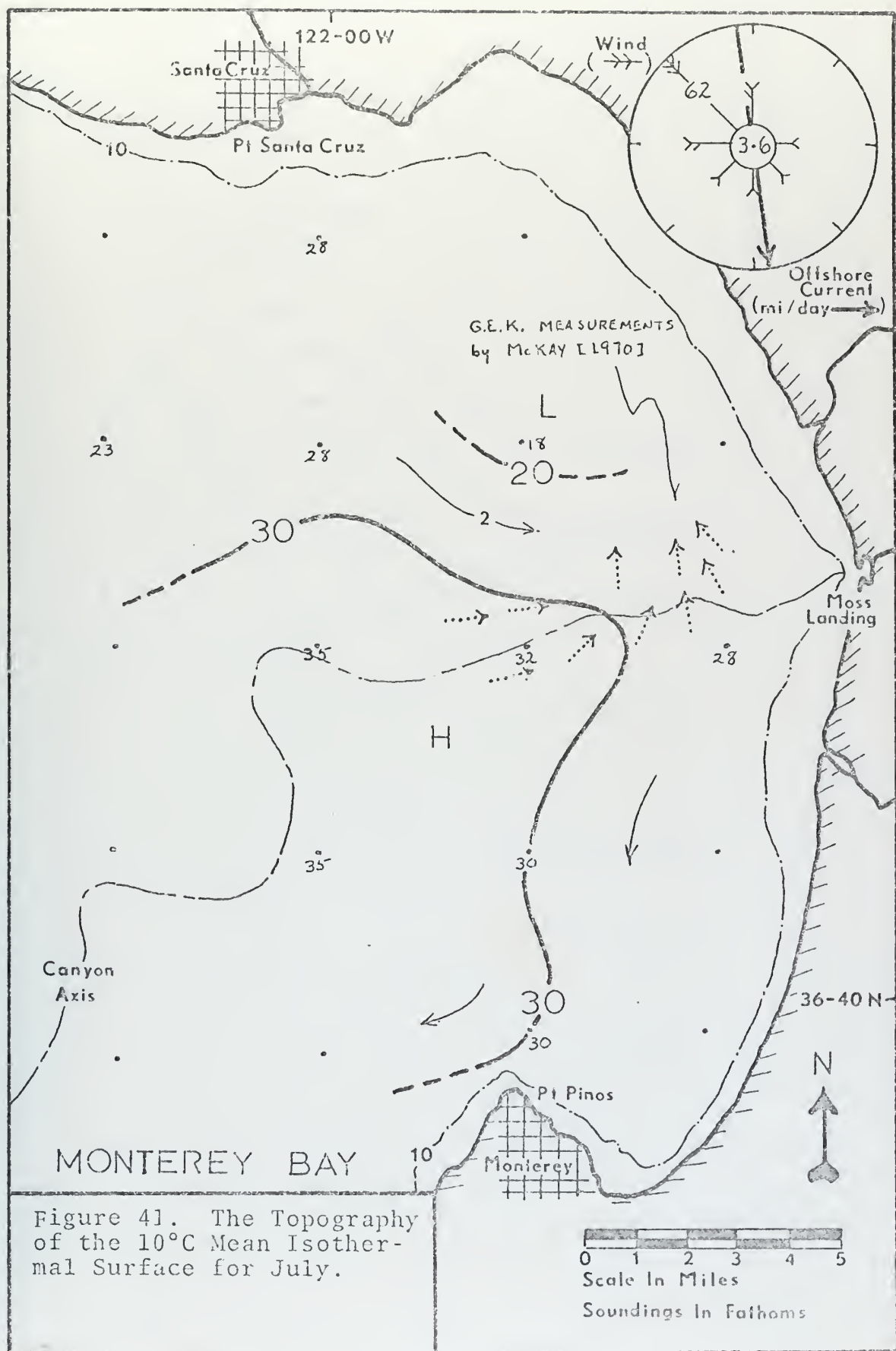


Figure 41. The Topography of the 10°C Mean Isothermal Surface for July.

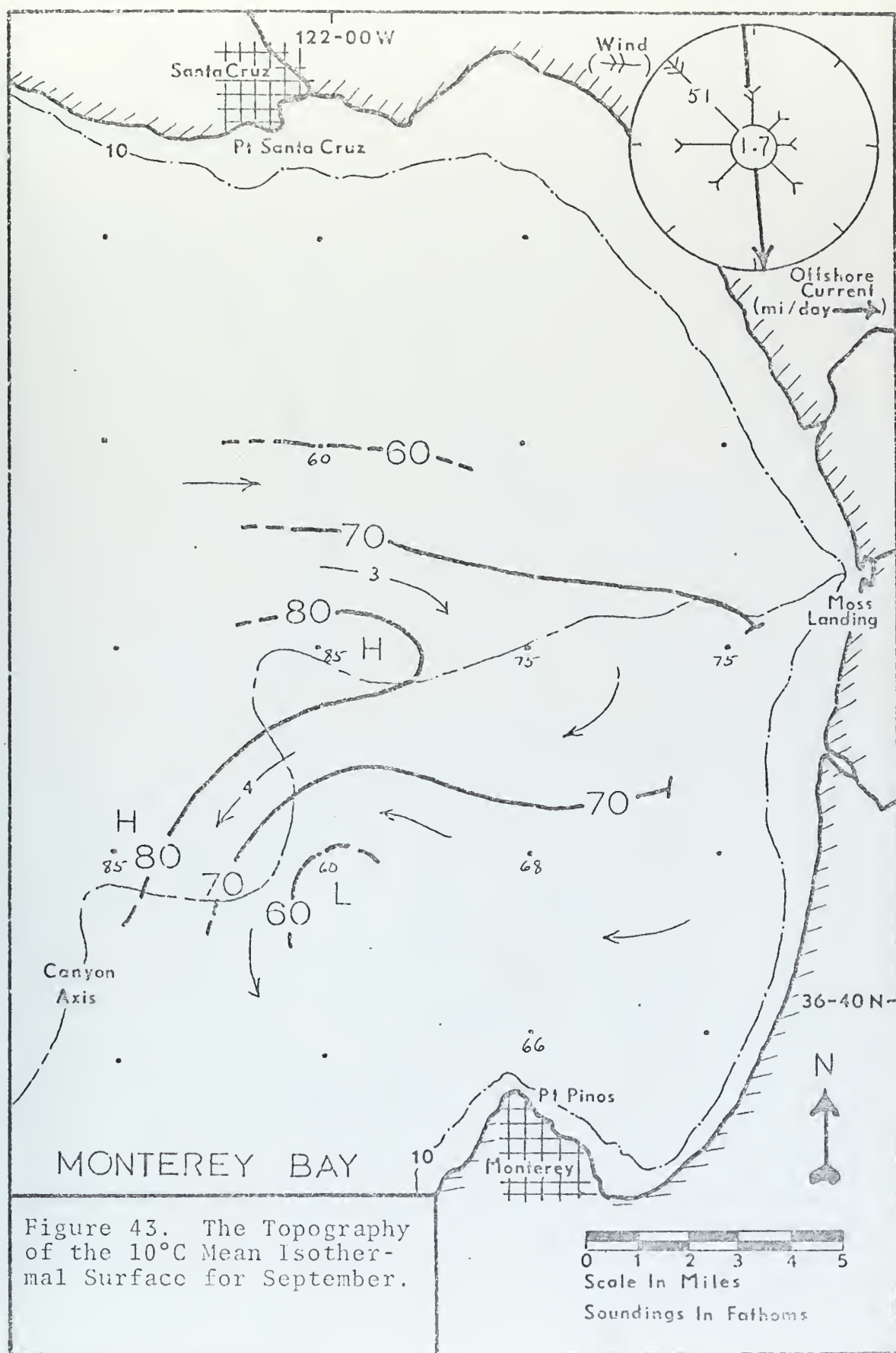




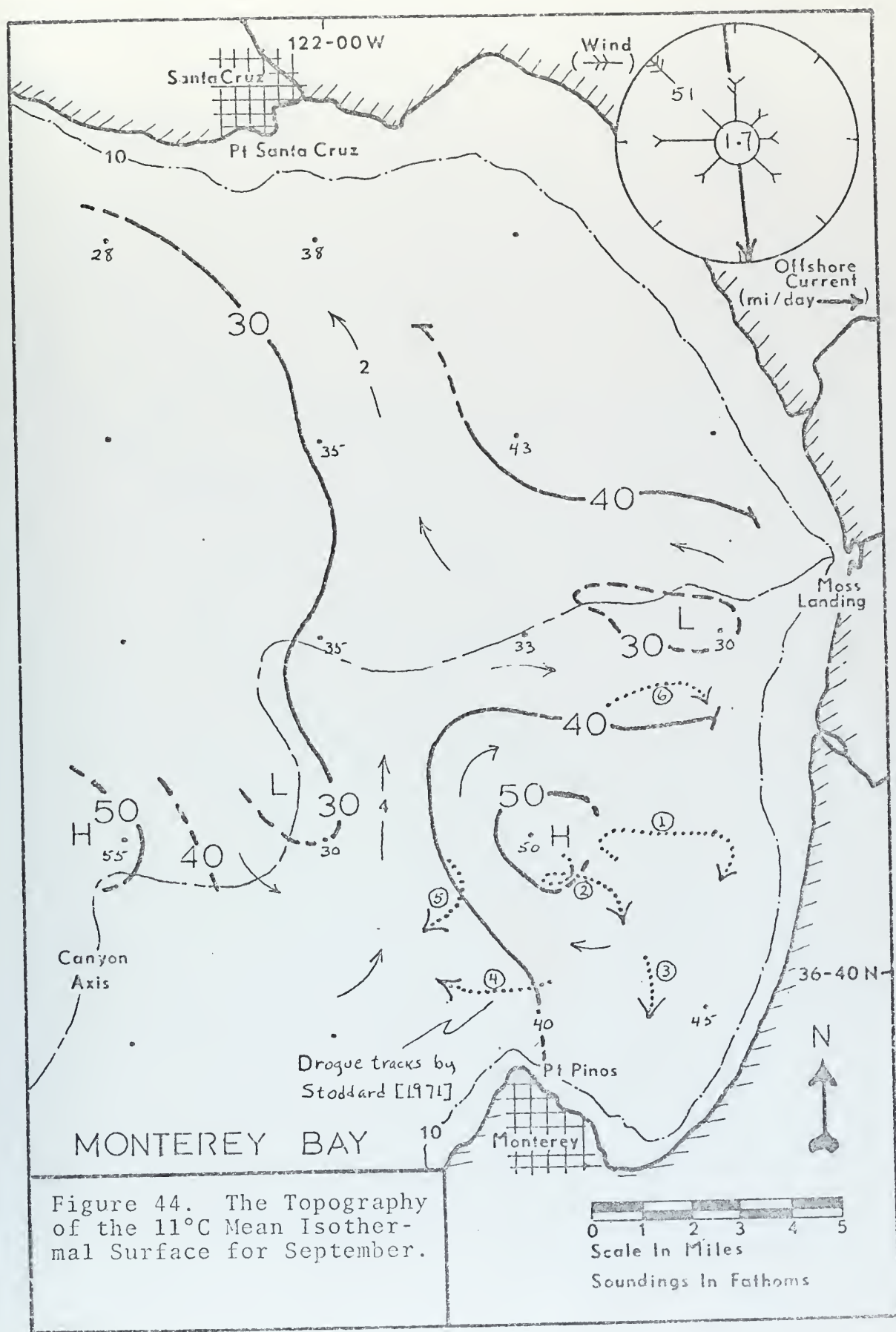




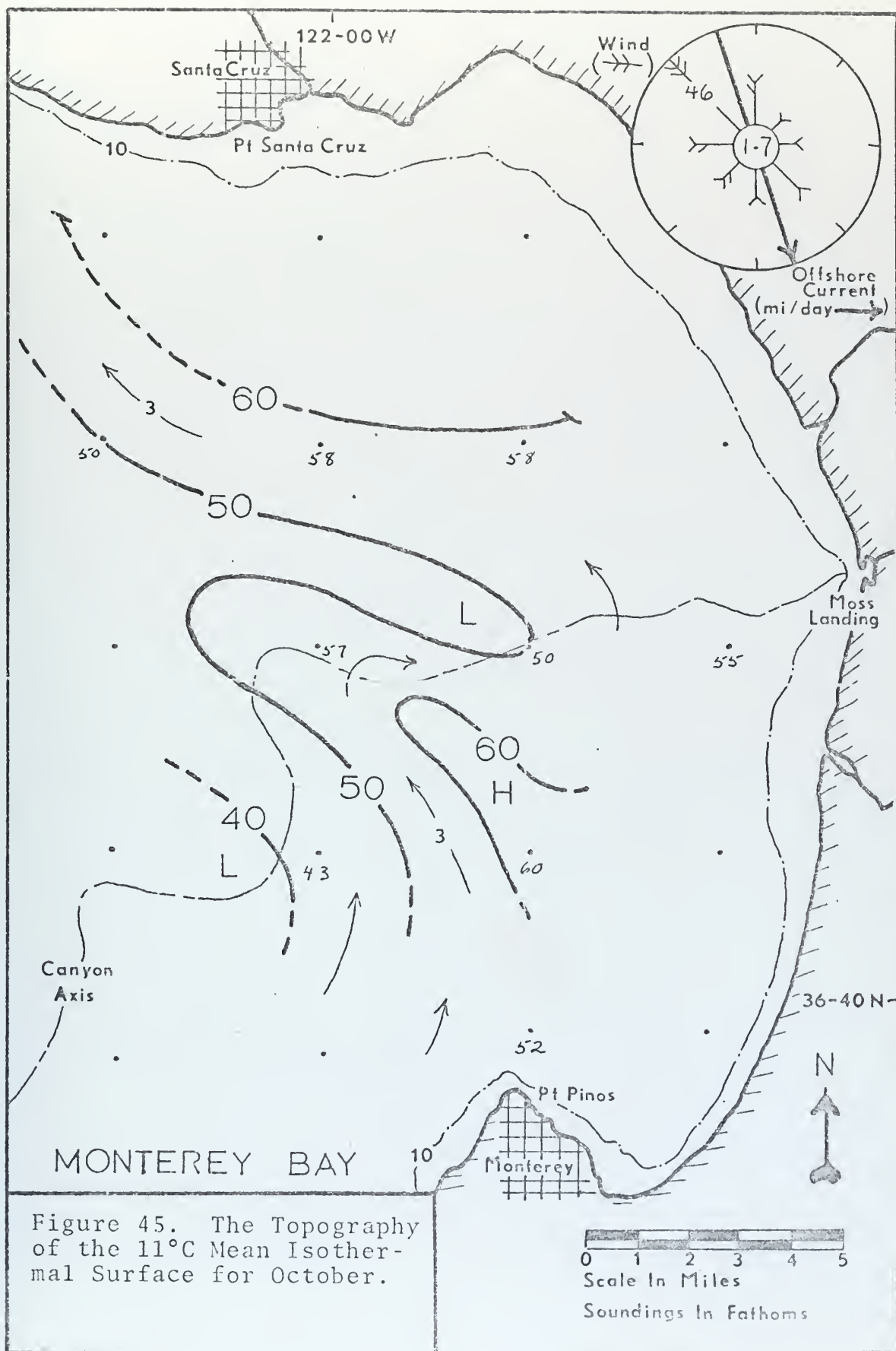














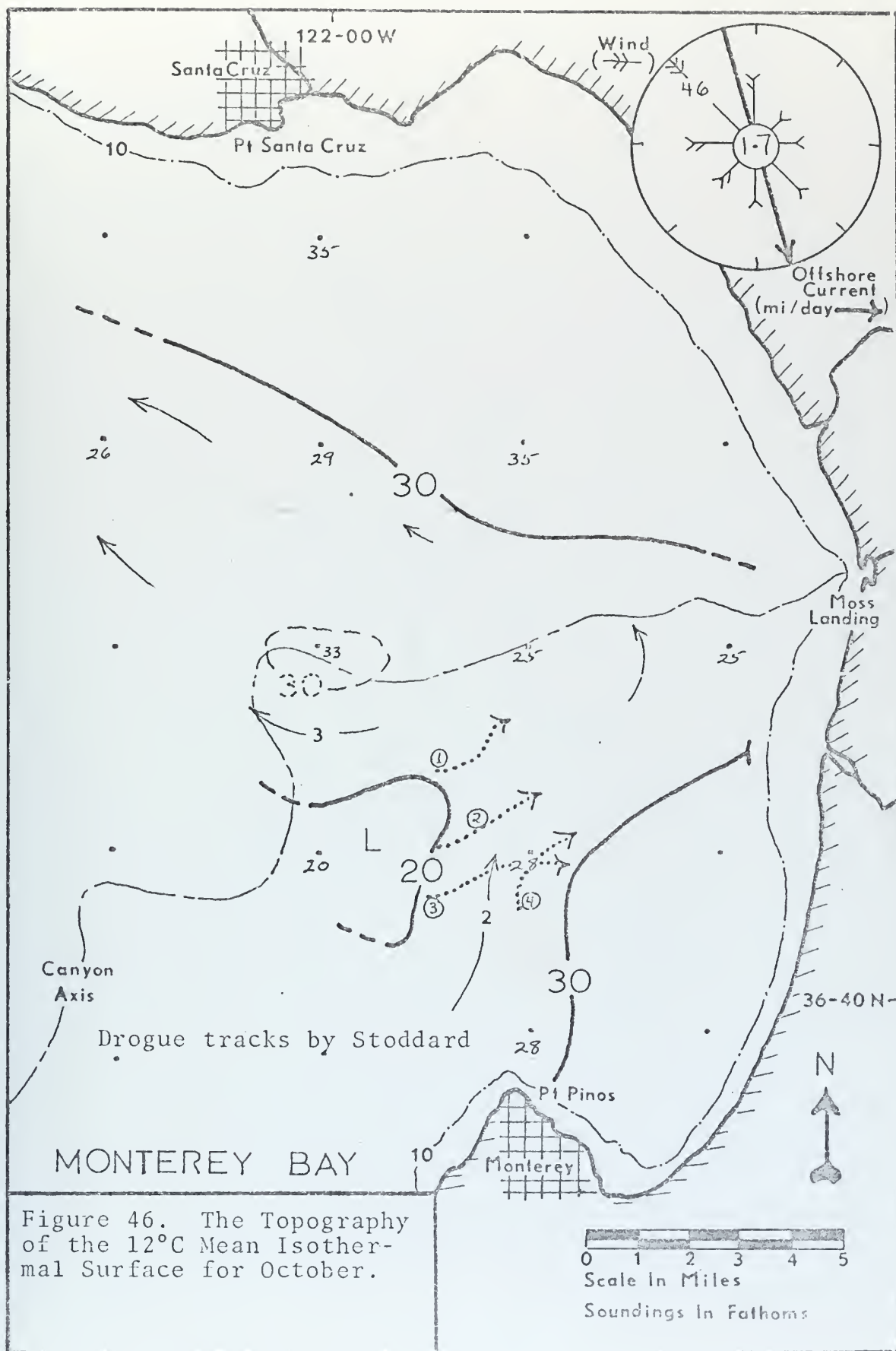


Figure 46. The Topography of the 12°C Mean Isothermal Surface for October.





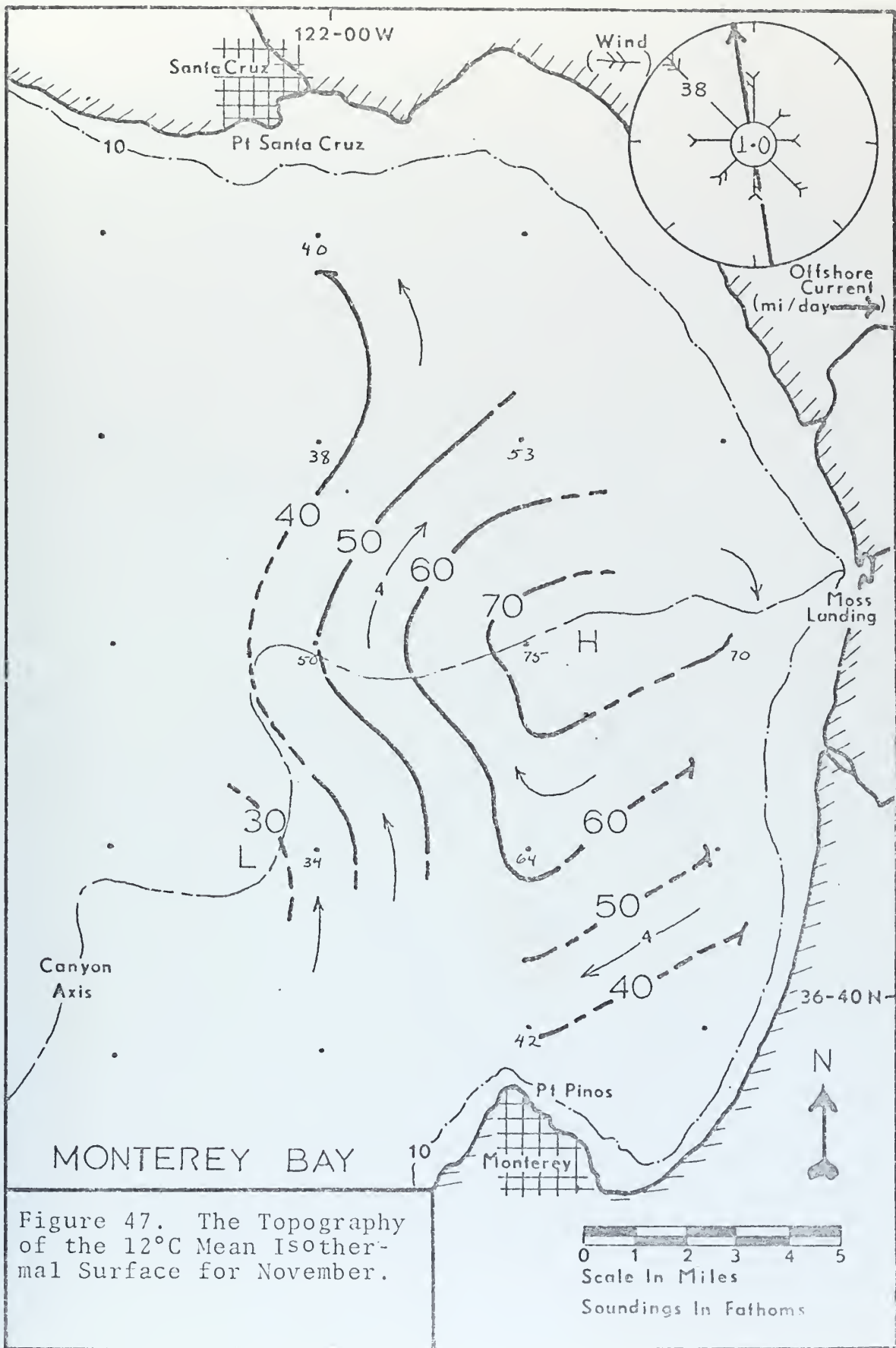
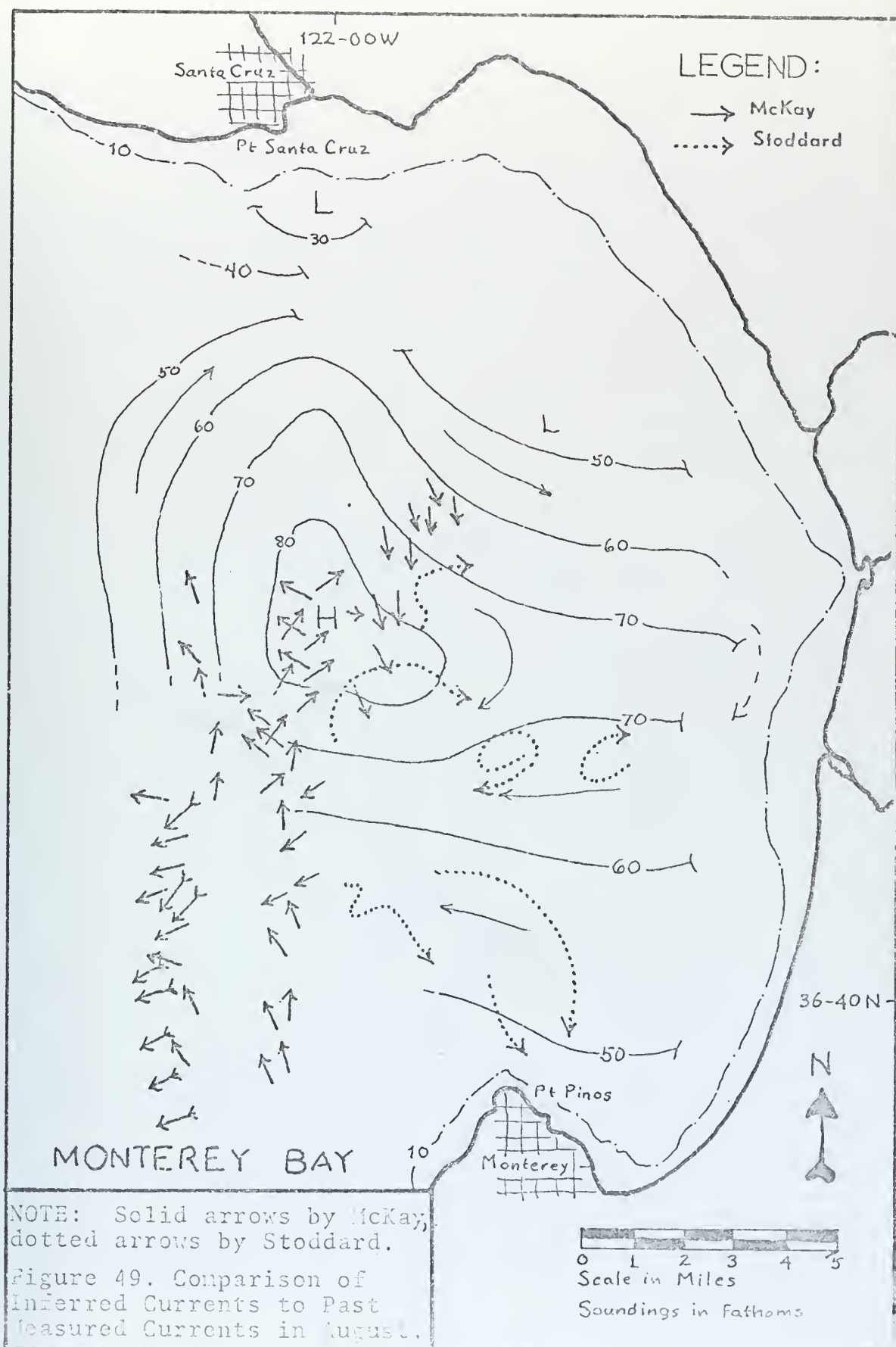


Figure 47. The Topography of the 12°C Mean Isothermal Surface for November.

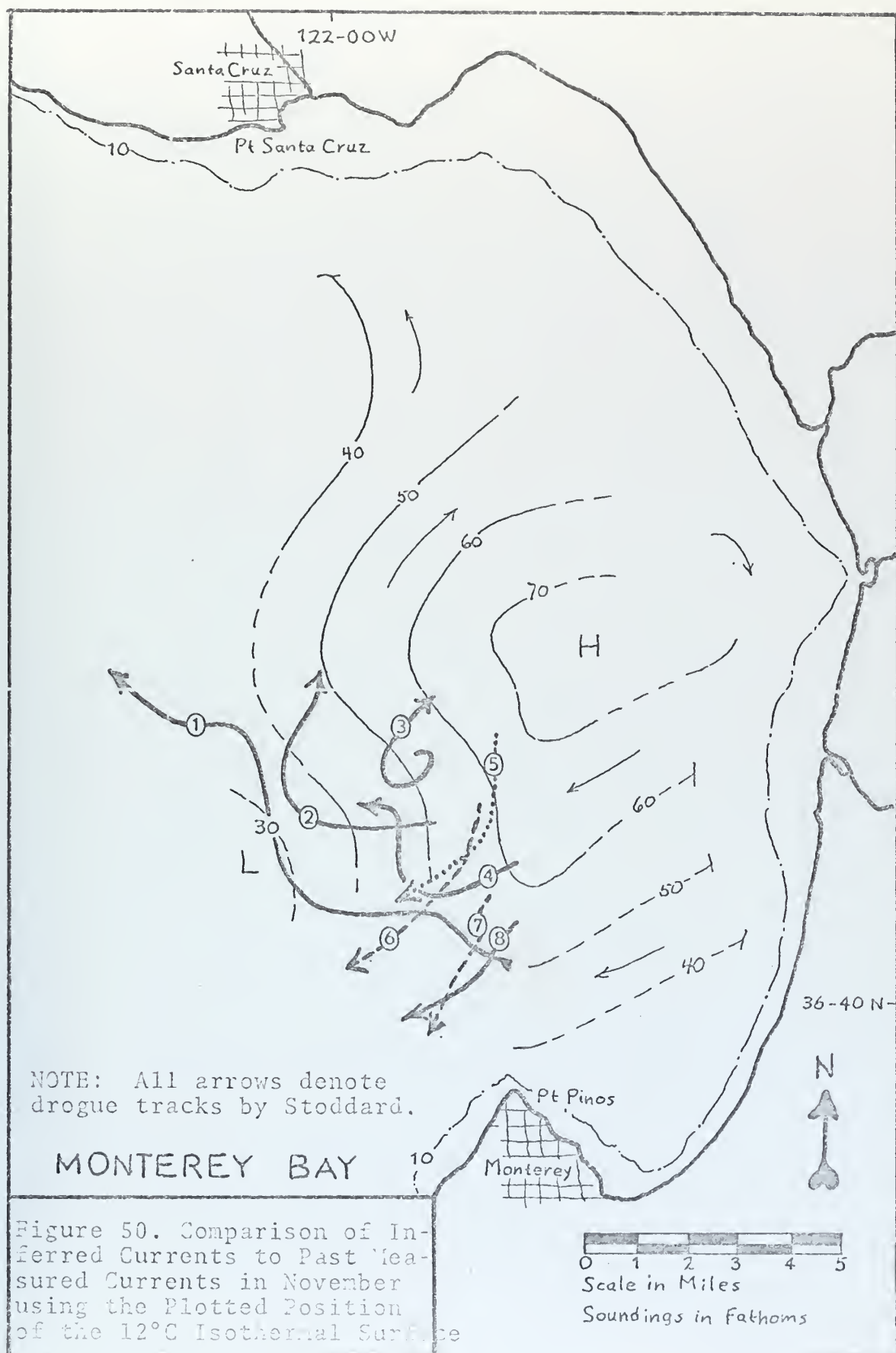






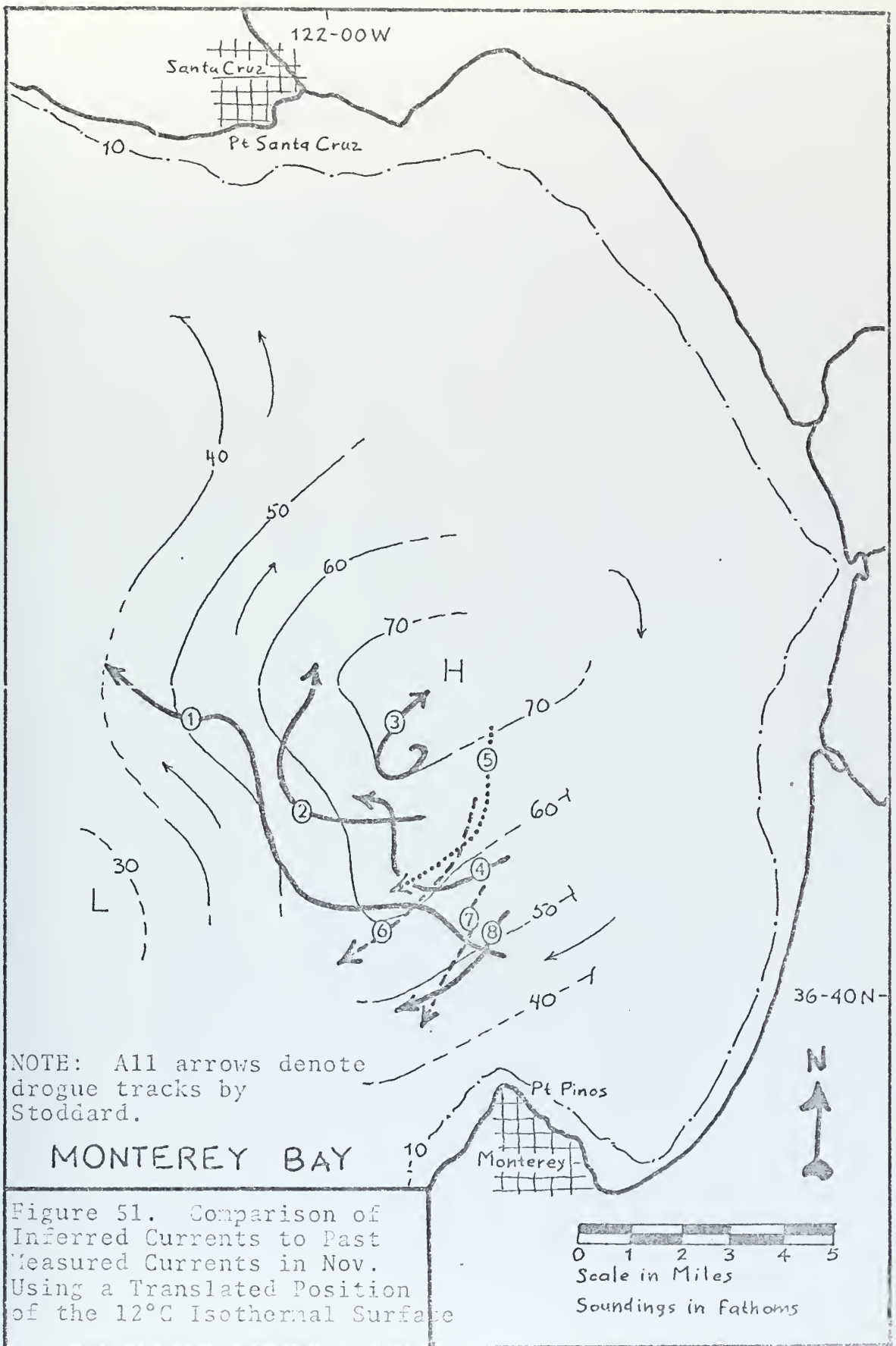














```
//LAMMO001 JOB (0687,0446FT,DEG9),'L.L.LAMMERS'
//EXEC FORTCLGP,REGION.GO=100K
//FCRT.SYSIN DD *
```

```
PROGRAM 1 L.L.LAMMERS 11 JAN 1971
```

```
THIS PROG READS BOLIN DATA IN OBSERVED FORM AND:
```

- (1) COMPUTES SIGMA-T
- (2) INTERPOLATES TO STD VALUES(ALL DATA)
- (3) PRINTS OUT DATA IN AUTHOR'S FORMAT
- (4) PUNCHED CARDS OUT IN AUTHOR'S FORMAT

```
WHEN DEBUGGED, ALL DATA WILL BE WRITTEN ON THE MASTER TAPE
```

```

DIMENSION DEP(20),TEM(20),SAL(20),SGT(20),STDEP(20),STEM(20),
$SAL(20),STSGT(20)
DATA IND//NANS//
DATA STDEP/C,10.,15.,20.,30.,50.,75.,100.,125.,150.,200.,250.,
$300.,400.,500.,600.,700.,800.,900.,1000./
DC 300 I=1,500
READ(5,500,END=1000,ERR=999) NDAY,NMO,NYEAR,NVAL
NVAL=NR OF DATA CARDS FOR TITLE CARD
FORMAT(3I2,1X,I2)
NOW READ DATA CARDS
DO 10 K=1,NVAL
  READ(5,501) DEP(K),TEM(K),SAL(K)
  FORMAT(F9.0,F10.2,F10.2)
  NOW CALCULATE SIGMA-T(SGT) FOR EACH OBSERVED DEPTH. ST,SO,CL,AT,
  BT ARE VARIABLES USED IN THE CALCULATION
  ST=-((TEM(K)-3.98)**2)/503.57*((TEM(K)+283.)/(TEM(K)+67.26))
  CL=(SAL(K)-.030)/1.805
  SC=-.069+1.4708*CL-.00157*CL**2+3.98E-5*CL**3
  AT=TEM(K)*(4.7867-.098185*TEM(K)+.0010843*TEM(K)**2)*1.E-3
  BT=TEM(K)*(18.030-.8164*TEM(K)+.01667*TEM(K)**2)*1.E-6
  SGT(K)=ST+(SO+.1324)*(1.-AT+BT*(SO-.1324))
CONTINUE
NOW INTERPGLATE FCOR STD DEPTHS THE VALUES STDEP,STEM,STSAL,STSGT
JJ COUNTS STD DEPTHS/TEMPS,KK COUNTS OBSERVED DEPTHS/TEMPS
JJ=0
KK=0
JJ=JJ+1
KK=KK+1
CHECK FOR LAST DATA CARD(CN THIS STATION)
IF(KK.GT.NVAL) GO TO 200
1ST OBS DEPTH MUST = 0 MET = 1ST STD DEPTH(JJ=1)
IF(JJ.EQ.1) GO TO 90

```



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062A  
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507 WRITE(6,507)
   FORMAT(//1X,'TOTAL NANS STA EXCEEDED 500, STOPPING')
   STOP
999 WRITE(6,508) I
508 FORMAT(//1X,'READ ERROR, STOPPING: NANS STA NR=',I6)
   STOP
1000 I=I-1
   WRITE(6,509) I
509 FORMAT(//1X,'END OF DATA:',10X,I4,3X,'NANS STA PROCESSED')
   STOP
   END
//GO.FT06F001 DD SPACE=(CYL,(3,1))
//GO.FT07F001 DD SPACE=(CYL,(3,1))
//GO.SYSIN DD *

```

\*\*\*\*\*

```

//LAMMC002 JOB (C687,0446FT,QEG9),'L.L.LAMMERS'
// EXEC FORTCLGP,REGION.GO=100K,TIME.GO=30
//FCRT.SYSIN DD *

```

PROGRAM 2 L.L.LAMMERS 15 NOV 1970

MODIFIES TO INCLUDE PUNCHING OUT OF DATA CARDS  
THIS PROGRAM READS IAPENPS264 TO DETERMINE:  
1. IF ANY XBT DATA EXISTS FOR MTRY BAY  
2. TO COUNT DATA CARDS THAT FOLLOW EACH TITLE CARD AND PRINT  
NR OF DATA CARDS FOLLOWING EACH TITLE CARD.  
3. THEN PRINT ALL TITLE AND DATA CARDS FOUND FOR MTRY BAY IN  
THE FORMAT:  
A. IF MTRY BAY, WRITE NEW TITLE CARD(NR DATA CARDS INCL)  
B. IF MTRY BAY, WRITE DATA CARDS

001  
002  
002A  
002B  
003  
004  
005  
006

```

DIMENSION KK(26),LL(26,50)
DATA 1BT//XBT//,KN//N//,KW//W//,LDS//,36//,LDL//,37//,
$LMS//,30//,LML//,10//,LODS//,121//,LODL//,122//,LOML//,30//
REWIND 2
IEND=0
READ FIRST TITLE CARD
READ(2,1) KK
1. FORMAT(10A4,2A2,A1,A2,A1,A4,A3,A1,A2,A1,4A4,I3,A2)
   NOW START OUTER LOOP TO READ 25000 XBT STATIONS
   DO 20 M=1,25000

```





```

C AND 121-30 TC 122-20W).
  IF(KK(15).NE.KN) GO TO 70
  IF(KK(20).NE.KW) GO TO 70
  IF(KK(12).EQ.LDS) GO TO 9
  IF(KK(12).EQ.LDL) GO TO 40
  GO TO 70
  9 IF(KK(14).GE.LMS) GO TO 19
  GO TO 70
  19 IF(KK(17).EQ.LDS) GO TO 69
  IF(KK(17).EQ.LODL) GO TO 30
  GO TO 70
  30 IF(KK(19).LE.LOML) GO TO 69
  GO TO 70
  40 IF(PK(14).LE.LML) GO TO 50
  GO TO 70
  50 IF(KK(17).EQ.LDS) GO TO 69
  IF(KK(17).EQ.LODL) GO TO 60
  GO TO 70
  60 IF(KK(19).LE.LOML) GO TO 69
  GO TO 70
  C WE GET TO 69 IFF TITLE CARD IS FOR MTRY BAY. NOW TURN ON IWR.
  69 IWR=1
  70 CONTINUE AND COUNT DATA CARDS UNTIL WE FIND ANOTHER TITLE CARD.
  C NOW READ DATA CARDS FOR US.
  C J COUNTS DATA CARDS FOR US.
  3 DO 10 J=1,50
  5 READ(2,1,END=21,ERR=8) (LL(I,J),I=1,26)
  C TEST FOR A TITLE CARD
  IF(LL(1,J).NE.IBT) GO TO 10
  C IF WE GET HERE WE HAVE A TITLE CARD
  GO TO 11
  8 WRITE(6,200) M,J
  200 FORMAT('OREAD ERROR',10X,'M=',I6,10X,'J=',I5)
  GO TO 5
  10 CONTINUE
  C WE SHOULD NEVER GET TO HERE. IF WE DO, J.GT.50 DATA CARDS
  GO TO 3
  21 IEND=1
  11 J=J-1
  IF(IWR.EQ.0) GO TO 44
  KK(25)=J
  C NOW WRITE NEW TITLE CARD WITH 'J' DATA CARDS WRITTEN ON IT
  WRITE(7,2) KK
  C NOW WRITE J DATA CARDS

```

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015D
015E
015F
015G
015H
015I
015J
015K
015L
015M
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018
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021
021A
021B
021C
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025
026
027
028
029
030

```







```

6 DATA LONMI(17),53.5,57.0,59.0,100.0,59.0,55.0,
7 "I"= A DATA SET(ONE MONTH'S AVGS; 6 STATIONS)
8 DC 200 I=1,500
9 READ A TITLE CARD
101 READ(5,101,END=500,ERR=400) NMO,NYEAR
102 FORMAT(2I2)
103 NOW READ 6 STATIONS(STA NR=L) 2 CARDS PER STA(K=DATA AT 0 & 15M)
104 DO 30 L=1,6
105 DO 10 K=1,2
106 READ DATA CARDS FOR STA NR " "
107 READ(5,102) TEM(K),SAL(K),SGT(K)
108 FORMAT(17X,3(F9.2,1X))
109 CONTINUE
110 ONE NANS STA READ IN;NOW ASSIGN & INTERPOLATE VALUES TO 0,10,15M
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```

106 WRITE(7,106) STDEP(JJ),STEM(JJ),STSAL(JJ),STSGT(JJ)
20  FORMAT(F5.0,1X,3(F5.2,1X))
C CONTINUE
30  NOW GET NEXT STATION NR (L)
C CONTINUE
C GET NEXT DATA SET(ANOTHER MONTH'S DATA)
200 CONTINUE
C SHOULD NEVER ARRIVE HERE(TOTAL DATA SETS.GT.500)
107 WRITE(6,107)
FORMAT(//1X,'ERROR: MORE THAN 500 DATA SETS, STOPPING')
STOP
400 WRITE(6,108) I
108 FORMAT(//1X,'READ ERROR, STOPPING: I=',I6)
STOP
500 I=I-1
I1=6*I
I11=24*I
WRITE(6,109) I1,I11
109 FORMAT(//1X,'END OF DATA: TOTAL OCEAN STA=',I6,5X,
$, 'TOTAL 80 BYTE RECORDS=',I8)
STOP
END
//GO.FT06F001 DD SPACE=(CYL,(3,1))
//GO.FT07F001 DD SPACE=(CYL,(3,1))
//GO.SYSIN DD *

```

\*\*\*\*\*

```

//LAMMCO04 JOB (0687,0446FT,0EG9),'L.L.LAMMERS'
//EXEC FORTCLG,TIME.GO=6
//FCRT.SYSIN DD *

```

PROGRAM 4 L.L.LAMMERS 22 JAN 1971

```

READS NODC NANSEN DATA FROM 7-TRACK TAPE(SER=R1019), AND:
1. COMPUTES NR OF DATA CARDS FOR EACH TITLE CARD(NR CARDS=J)
2. WRITES NEW TITLE CARD WITH J IN COLUMNS 79-80
3. WRITES J DATA CARDS
**DATA WRITTEN ONTO NPGS 9-TRACK TAPE(SER=NPS297)
(A 9-TRACK TAPE) FOR LATER PROCESSING IN AUTHOR'S FORMAT

DIMENSION INDATA(19),NSAVE(35,19)
DATA NTOT/O/,N/O/,JTOT/O/,I/O/
NTOT=TOTAL NR OF 80 COLUMN RECOFDS WRITTEN(NTOT=M+JTOT)

```

32  
33  
34  
35  
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40

43  
44

1  
2

















```

24  T15=TEM(3)-(C1*(TEM(3)-TEM(2)))/C2
25  NOW SALINITY AND SIGMA-T
26  IF((SAL(2).EQ.0).OR.(SAL(3).EQ.0.0)) GO TO 95
27  SL15=SAL(3)-(C1*(SAL(3)-SAL(2)))/C2
28  SGT15=SGT(3)-(C1*(SGT(3)-SGT(2)))/C2
29  GO TO 200
30  T15=0.0
31  SL15=0.0
32  SGT15=0.0
33  GO TO 200
34  SL15=0.0
35  SGT15=0.0
36  AT 200 WITH ONE STATION READY TO BE WRITTEN
37  M DEFINES TOTAL NANS STA WRITTEN(OR TITLE CARDS)
38  JTOT DEFINES TOTAL NR OF STATION DATA CARDS WRITTEN
39  NTOT=M+JTOT DEFINES TOTAL NR OF 80-BYTE RECORDS WRITTEN
40  M=M+1
41  MUST INCREASE NCARDS BY ONE TO INCLUDE THE 15M VALUES
42  NCARDS=NCARDS+1
43  JTOT=JTOT+NCARDS
44  NOW WRITE A TITLE CARD IN AUTHOR'S FORMAT
45  $RLONMI,NREF1,NREF2,NREF3
46  $7X,3A4,5X,1X,1X,NANS,1X,3(I2,1X),I4,2X,I2,1X,F4.1,2X,I3,1X,F4.1,
47  $7X,3A4,5X,1X,NODC TAPE=R1019;)
48  $RLONMI,NREF1,NREF2,NREF3
49  $7X,3A4,5X,1X,NANS,1X,3(I2,1X),I4,2X,I2,1X,F4.1,2X,I3,1X,F4.1,
50  $7X,3A4,5X,NODC TAPE=R1019;)
51  SET NCARDS BACK ONE TO ORIGINAL NUMBER
52  NCARDS=NCARDS-1
53  NOW WRITE DATA CARDS. NOTE: THE 3RD DATA CARD IS FOR T15,SL15,...
54  DO 250 JJ=1,NCARDS
55  IF(JJ.EQ.3) GO TO 230
56  WRITE(6,105) DEP(JJ),TEM(JJ),SAL(JJ),SGT(JJ)
57  FORMAT(1X,105) DEP(JJ),TEM(JJ),SAL(JJ),SGT(JJ)
58  WRITE(10,106) DEP(JJ),TEM(JJ),SAL(JJ),SGT(JJ)
59  FORMAT(F5.0,1X,3(F5.2,1X))
60  GO TO 250
61  WRITE(6,105) DEPI5,T15,SL15,SGT15
62  WRITE(10,106) DEPI5,T15,SL15,SGT15
63  NOW GO BACK TO 210 AND WRITE J=3,NCARDS DATA
64  GO TO 210
65  CONTINUE
66  ONE STATION WRITTEN. GO BACK FOR NEXT ONE
67  CONTINUE
68  WRITE(6,107) M

```









```
C
DIMENSION INDATA(20)
REWIND 8
REWIND 9
J=0
J=J+1
20 READ(8,101,END=50,ERR=40) INDATA
101 FORMAT(20A4)
WRITE(9,101) INDATA
GC TO 20
40 WRITE(6,102) J
102 FCRMAT(/5X,'READ ERROR,RECORD NR=',I8)
GO TO 20
50 WRITE(6,103) J
103 FCRMAT(/5X,'END OF TAPE, RECORD NR=',I8)
END FILE 9
REWIND 9
NOW SEE IF CONVERSION WAS SUCCESSFUL. WRITE OUT 25 LOG RCDS FROM
TAPE NR 9
DC 80 JJ=1,25
READ(9,101,ERR=90) INDATA
WRITE(6,104) INDATA
104 FCRMAT(IX,20A4)
80 CCNTINUE
STOP
90 WRITE(6,105) JJ
105 FCRMAT(IX,'READ ERROR,TAPE NR 9,STCIPPING: RCDNR=',I4)
STOP
END
//GC.FT08F001 DD UNIT=2400-1,VOL=SER=R1030,LABEL=(,NL),TRTCH=ET)
//GC.FT09F001 DD UNIT=2400,VOL=SER=NPS296,LABEL=(,SL),DSNAME=LAMMERS,
// DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
*****
//LAMMOO07 JOB (0687,0446FT,CEG9),'L.L.LAMMERS'
// EXEC FORTCLG,TIME.GQ=6
//FCRT.SYSIN DD *
*****
PROGRAM 7 L.L.LAMMERS 22 JAN 1971
*****
READS 9-TRACK TAPE(NPS296), CONTAINING NODC-BT DATA, AND WRITES
DATA OUT ONTO MASTER TAPE(NPS306) IN AUTHOR'S FORMAT
```

















```

12 FORMAT (10X, '*' INDICATES ADJUSTED VALUE')
13 FORMAT (I4,3A4,F3.0,2F5.1,F4.1,3A4)
14 FCRMAT (8F10.3)
15 FCRMAT (F10.3,F9.2,A1,F10.3,A1,F8.2,A1,8X,4A8)
16 FCRMAT (10X, 'DEPTH TEMPERATURE SALINITY SIGMA-T OXYGEN'//)
17 FCRMAT (20X, 'OBSERVED VALUES'//)
18 FCRMAT (/20X, 'INTERPOLATED VALUES'//)
19 FCRMAT (10X, 'DEPTH TEMPERATURE SALINITY SIGMA-T SND VEL SPE
1C VOL SPEC V ANOM MEAN SVA DELTA D DYNAMIC HEIGHT'//)
20 FCRMAT (10X,F5.0,F10.2,F12.3,F9.3,F12.2,F10.4,F12.6,25X,F10.5/80X,
12F12.6)
21 FCRMAT (10X,F5.0,F10.2,A1,F11.3,A1,F8.3,F9.2,A1,4X,4A8/)
DATA IN,'NANS',/12/'NPGS'/
DATA MO,'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG',
$ 'SEP','OCT','NOV','DEC',/
DATA SD/0.,10.,15.,20.,30.,50.,75.,100.,125.,150.,200.,250.,300.,
$ 400.,500.,600.,700.,800.,900.,1000.,1100.,1200.,1300.,1400./
JTOT=0
NTOT=0
NSD=24
READ (5,13) NGC
IF (NGC.EQ.0) GO TO 410
READ (5,9) (NPA(I),NPB(I),SLEV(I),I=1,NGC)
410 NPA(NGC+1)=0
DC 41 L=1,48
C READ HEADING CARD, CHECK FOR END OF DATA, THEN
C READ NCV DATA CARDS.
C
C READ(5,51,END=99,ERR=98) NOV,{NSTA(L,K),K=1,3},ALT(L),ALM(L),
$ ALN(L),ANM(L),NDAY,NMO
51 FCRMAT (I4,3A4,F3.0,2F5.1,F4.1,2X,A2,1X,A3)
NEXT LOOP CONVERTS NMO FROM A-4 TO NUMERIC(I.E..01,02,....,12)
DC 22 LL=1,12
IF (NMO.EQ.MO(LL)) GO TO 23
CONTINUE
22 WRITE(6,600) L,NMO
600 FCRMAT (1X, MONTH CODED IMPROPERLY, STOPPING: NANS STA NR=' , I4, 5X,
$ , MO=' , 3X, A3//)
STOP
23 CONTINUE 32,32,24
IF (NOV) 32,32,24
DO 25 I=1,NCV
24 READ (5,15) D(I),T(I),IT(I),S(I),IS(I),O2(I),IO(I),
1(INFQ(I;J),J=1,4}
C
C
C SGT SVA IS SUBROUTINE TO COMPUTE SIGMA-T, SPECIFIC VOLUME
AND SPECIFIC VOLUME ANOMALY.

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0028C  
0028D  
028E  
0028F  
0028G  
0028H  
0028I  
0028J

0020A



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CALL LGTP(NOV,D,T,NSD,SD,ST,NA)
CALL LGTP(NOV,D,S,NSD,SD,SS,NB)
NO(L)=NA
DO 27 I=1,NA
CALL SNDVEL (ST(I),SS(I),SD(I),SNDV(I))
CALL SGT SVA (ST(I),SS(I),SD(I),SGT(I),SV(I),SVA(I))
CCNT INUE
NLT=ALT(L)
MLN=ALN(L)
WRITE(6,50) NA,IN,NDAY,LL,NLT,ALM(L),NLN,ANM(L),IZ,(NSTA(L,K),K=2,
$3)
50 FORMAT(1X,I2,1X,A4,1X,A2,1X,I2,1X,'67',7X,I2,1X,F4.1,2X,I3,1X,
$F4.1,24X,3A4)
WRITE(10,70) NA,IN,NDAY,LL,NLT,ALM(L),NLN,ANM(L),IZ,(NSTA(L,K),K=2
$3)
70 FORMAT(1X,I2,1X,A4,1X,A2,1X,I2,1X,'67',7X,I2,1X,F4.1,2X,I3,1X,F4.1,
$24X,3A4)
DO 31 I=1,NA
WRITE(6,52) SD(I),ST(I),SS(I),SGT(I)
52 FORMAT(1X,F5.0,1X,3(F5.2,1X))
71 WRITE(10,71) SD(I),ST(I),SS(I),SGT(I)
31 CCNT INUE
JTOT=JTOT+NA
41 CONTINUE
IF (NGC.EQ.0) GO TO 33
32 DO 42 L=1,48
IF (NPA(L).EQ.0) GO TO 33
BASE=SLEV(L)
N1=NPA(L)
N2=NPB(L)
NU1=NC(N1)
NU2=NC(N2)
DO 43 I=1,NU1
ADH(I)=DHT(N1,I)
43 DO 44 I=1,NU2
BDH(I)=DHT(N2,I)
NLT=ALT(N1)
MLN=ALN(N1)
MLT=ALT(N2)
MLN=ALN(N2)
WRITE (6,8) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NLN,ANM(N1),
1 (IDATE(N1,K),K=1,3),(NSTA(N2,K),K=1,3),MLT,ALM(N2),MLN,

```

0057A  
0058A  
0058C



```

2ANM(N2), (IDATE(N2,K),K=1,3)
  ALAT=ALN(N1)+ALM(N1)/60.
  ALON=ALN(N1)+ANM(N1)/60.
  BLAT=ALN(N2)+ALM(N2)/60.
  BLON=ALN(N2)+ANM(N2)/60.
  CALL DSTSTA (ALAT,ALON,BLAT,BLON,X2)
  CALL GEOCUR (NU1,ADH,NU2,BDH,SD,BASE,X2)
42  WRITE(6,601) L
58  FORMAT(//, READ ERROR, STOPPING: NANS STA NR=, 5X, I4)
601 STOP
99  L=L-1
  NTOT=JTOT+L
  WRITE(6,602) L,NTOT
602 FORMAT(//IX, END OF DATA: TOT NANS STA=, I6, 5X, TOT 80-BYTE REC=,
  $ I6)
33 STOP
END

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```

SUBROUTINE GEOCUR (NA,ADH,NB,BDH,SD,BASE,X2)
DIMENSION ADH(NA),BDH(NB),SD(24),RVEL(24),VEL(24),AMB(24)
10  FORMAT (13X, 'DEPTH DYN HT STA A STA B A-B REL VEL ABS
  1VEL CM/SEC', /)
2  FORMAT (13X, F5.0, 2X, 3(F9.5, 1X), 2(F8.2, 2X) /)
11  FORMAT (13X, '*** LEVEL OF NO MOTION MUST BE EQUAL TO A STANDARD DEPT
  1H ***')
  IF(NA.LE.NB) GO TO 51
  N=NB
  GO TO 52
51  N=NA
52  DC 53 I=1, N
  AMB(I)=ADH(I)-BDH(I)
53  RVEL(I)=AMB(I)*X2
  DO 54 I=1, 24
  IF(BASE.EQ.SD(I))GO TO 55
54  CONTINUE
  WRITE (6,12)
  GO TO 70
55  NM=I
  IF(NM.GT.N) NM=N
  DO 56 I=1, N
  RVEL(I)=RVEL(NM)-RVEL(I)
56  WRITE (6,10)
  DO 60 I=1, N
  SD(I),ADH(I),BDH(I),AMB(I),RVEL(I),VEL(I)
60  WRITE (6,11)
  RETURN
70  END

```





```

SUBROUTINE USISTA (SATI,UNGI,SATI,UNGI1,X2)
IMPLICIT REAL*4 (K)
REAL*8 A,REAL*4 B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z
DATA A/111132.09/,B/566.05/,C/1.20/,D/-0.002/
DATA E/1111415.13/,F/94.55/,G/0.12/
FORMAT (10X,'MEAN LATITUDE = ',F6.2/15X,'DISTANCE = ',F6.2,
10 1,'KILOMETERS',/)
CCN=2*3.1416/360
AATI=SATI*CCN
AMERI=A-B*CCS(2*AATI)+C*CCS(4*AATI)-D*CCS(6*AATI)
PARI=E-COS(3*AATI)+G*CCS(5*AATI)
$MERII=A-B*CCS(2*AATI)-F*CCS(4*AATI)+G*CCS(6*AATI)
$MERII=E-COS(3*AATI)-F*CCS(4*AATI)+G*CCS(5*AATI)
ALLAT=((PARI+AMERI)/2
ALLON=((PARI-SATI)
DLAT=SATI-UNGI1
DLONG=DLAT*ALLAT/1000
KLONG=DLON*ALLON/1000
KDIX=SQRT(KLAT**2+KLONG**2)
W2=1.458E-4
PSI=(SATI+SATI)*0.5
PSJ=(2.*3.14159/360.)*PSI
SPSI=SI*LT*0.1,SPSI=0.1
X2=1./W2*SPSI*KDIX
WRITE(6,10) PSI,KDIX
RETURN
END

```

```

SUBROUTINE LGTP(N,D,V,M,SD,CV,NN)
DIMENSION D(N),V(N),CV(M),SD(M)
DO 183 J=1,N
DO 186 I=1,M
IF(SD(J)-D(I))113,115,190
CV(J)=V(N)
GO TO 191
IF(SD(J)-D(I))114,114,116
CV(J)=V(I)
GO TO 188
IF(SD(J)-D(I+1))120,118,186
CV(J)=V(I+1)
GO TO 188
IF(I-1)132,132,126

```



```

126  XA=(SD(J)-D(I))*(SD(J)-D(I+1))*V(I-1)/
1    ((D(I-1)-D(I))*(D(I-1)-D(I+1)))
127  XB=(SD(J)-D(I-1))*(SD(J)-D(I+1))*V(I)/
1    ((D(I)-D(I-1))*(D(I)-D(I+1)))
128  XC=(SD(J)-D(I-1))*(SD(J)-D(I+1))*V(I+1)/
1    ((D(I+1)-D(I-1))*(D(I+1)-D(I)))
129  ANSU=XA+XB+XC
130  IF ((I+2)-N) 133,134
131  YA=(SD(J)-D(I+1))*(SD(J)-D(I+2))*V(I)/
1    ((D(I)-D(I+1))*(D(I)-D(I+2)))
132  YB=(SD(J)-D(I-1))*(SD(J)-D(I+2))*V(I+1)/
1    ((D(I+1)-D(I-1))*(D(I+1)-D(I+2)))
133  YC=(SD(J)-D(I-1))*(SD(J)-D(I+1))*V(I+2)/
1    ((D(I+2)-D(I-1))*(D(I+2)-D(I+1)))
134  ANSD=YA+YB+YC
135  ZA=(SD(J)-D(I+1))*V(I)/(D(I)-D(I+1))
136  ZB=(SD(J)-D(I))*V(I+1)/(D(I+1)-D(I))
137  ANSL=ZA+ZB
138  IF (I-1) 136,138
139  CV(J)=(ANSD+ANSL)/2.
140  DLL=(ANSD+ANSL+ANSL)/3.
141  GO TO 188
142  IF ((I+2)-N) 140,142
143  CV(J)=(ANSD+ANSL)/3.
144  UD=(ANSD+ANSL)/2.
145  GO TO 188
146  CV(J)=(ANSD+ANSL)/2.
147  ULL=(ANSD+ANSL)/3.
148  GO TO 188
149  CONTINUE
150  CONTINUE
151  J=J-1
152  NN=J
153  RETURN
154  END

```

SUBROUTINE SNDVEL (T,S,D,SVL)

```

155  IF (D.LE.100.) GO TO 10
156  IF (D.LE.200.) GO TO 20
157  IF (D.LE.400.) GO TO 30
158  IF (D.LE.700.) GO TO 40
159  IF (D.LE.1500.) GO TO 50
160  IF (D.LE.2000.) GO TO 60
161  P=D*(.10318+(D-2000.)*2.6E-7)
162  GO TO 5
163  P=D*(.10245+D*3.0E-7)
164  GO TO 5

```



```

40 P=D*(.10267+(D-400.)*4.33E-7)
   GO TO 5
50 P=D*(.10280+(D-700.)*3.0E-7)
   GO TO 5
60 P=D*(.10304+(D-1500.)*2.7E-7)
   CONTINUE
5 VT=T*(.45721-T*(.044532-T*(2.6045E-4+T*(7.9851E-6))))
VP=P*(.160272+P*(1.0268E-5+P*(3.5216E-9-P*(3.3603E-12))))
VS=(S-.35)*(1.39799+(S-.35)*1.69202E-3)
A1=T*(-.011244+3.1580E-8*P+T*(7.7711E-7+1.5750E-9*P))
A2=P*(7.7016E-5-1.2943E-7*P)
A3=P*T*(-1.8607E-4+T*(7.4812E-6+T*(4.5283E-8)))
A4=P*P*(T*(-2.5204E-7+T*1.8565E-9)+P*T*(-1.9646E-10))
SVL=1449.14+VT+VP+VS+(S-.35)*(A1+A2)+A3+A4
RETURN
END

```

```

SUBROUTINE SGT(SVA (T,S,D,SGT,SV,SVA)
ST=-((T-3.98)**2)/503.57)*((T+283.)/(T+67.26))
CL=(S-.030)/1.805
SD=-.069+1.4708*CL-.00157*CL**2+3.98E-5*CL**3
AT=T*(4.7867-.098185*T+.0010843*T**2)*1.E-3
BT=T*(18.030-.8164*T+.01667*T**2)*1.E-6
SGT=ST+(SD+.1324)*(1.-AT+BT*(SD-.1324))
AFST=1./(1.+SGT*1.E-3)
A=D*AFST*1.E-9
B=4886./(1.+1.83E-5*D)
C=227.+28.33*T-.551*T**2+.004*T**3
E=D*1.E-4
G=(SD-28.)/10.
H=147.3-2.72*T+.04*T**2
U=105.5+9.5*T-.158*T**2
V=1.5*D**2*T*1.E-8
W=32.4-.87*T+.02*T**2
X=4.5-.1*T
Y=1.8-.06*T
SV=AFST-A*(B-C+E*U-V-G*(H-E*W)+G**2*(X-E*Y))
AZ=.972643
YA=-227.+01055*D
YB=.01266*(147.3-.00324*D)
AP=AZ-D*AZ*(B+YA-YB)*1.E-9
SVA=SV-AP
RETURN

```



```

//GO.FT10FOO1 DD UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//DISP=(MOD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
*****
//LANM0009 JOB (0687,0446FT,DEG9),'L.L.LAMMERS'
//EXEC FORTCLG,TIME.GO=2
//FCRT.SYSIN DD *
*****
PROGRAM 9 L.L.LAMMERS 29 JAN 1971
*****
READS MASTER TAPE(SER=NPS306) AND POSITIONS TAPE TO OC. STATION
NR 1535. THENCE CALCOFI, BOLIN, AND FNWC-XBT DATA CARDS ARE WRITTEN
ONTO MASTER TAPE.
*****
DIMENSION ITITLE(20),NDATA(20)
DATA KTOT/0/,LTOT/0/,JTOT/0/,NTOT/0/
READ DUMMY VALUES ON NPS306 TO POSITION TO OC STA=1535 FOR WRITE.
DC 20 II=1,1534
READ(10,301) NCARDS
FORMAT(12)
IF(NCARDS.EQ.0) GO TO 250
DO 10 JJ=1,NCARDS
READ(10,302) DUMMY
FORMAT(A4)
CONTINUE
KTOT=KTOT+NCARDS
CONTINUE
C GET HERE WITH 1534 OC STA READ. FIRST WRITE TOT 80-BYTE RECORDS
LTOT=1534+KTOT
WRITE(6,303) LTOT
303 FORMAT(//IX,'TAPE SEQUENCED: OC STA=1534',5X,'TOT 80-BYTE REC=',
$I8)
C NGW READY TO READ FROM UNIT 5 AND WRITE CN NPS306
DO 200 I=1,5000
C READ A TITLE CARD
READ(5,101)END=190) NCARDS,(ITITLE(L),L=1,20)
FORMAT(12,IX,A1,19A4)
IF(NCARDS.EQ.0) GO TO 260
WRITE ITITLE CARD
WRITE(10,101) NCARDS,(ITITLE(-),L=1,20)
C NGW READ AND WRITE DATA CARDS

```

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 3 4 5 4





```

C      NOW WRITE DATA CARDS
C      WRITE(10,103) (NDATA(LL),LL=1,20)
C      CONTINUE
C      150 JTOT=JTOT+NCARDS
C      JTOT=JTOT+NCARDS
C      CONTINUE
C      200 WRITE(6,105) JTOT
C      105 FORMAT(//1X,'MORE THAN(I=) 5000 OC. STA: TOT DATA CARDS WRITTEN=',
C      $I8)
C      STOP
C      190 I=I-1
C      IF(I) 190
C      190 JTOT=JTOT+NCARDS
C      106 WRITE(6,106) I,JTOT
C      106 FORMAT(//1X,'END OF DATA(NORMAL): TOT OCEAN STA=',I6,5X,'TOT 80-BY
C      $TE REC=',I8)
C      STOP
C      195 WRITE(6,107) I,J
C      107 FORMAT(//1X,'ERROR**END OF DATA(ABNORMAL): I=',I6,5X,'J=',I8)
C      STOP
C      250 WRITE(6,108) II
C      108 FORMAT(//1X,'NCARDS=0,STOPPING: II=',I8)
C      STOP
C      260 WRITE(6,109) I
C      109 FORMAT(//1X,'NCARDS=0,STOPPING: I=',I8)
C      STOP
C      END
C      //GO.FT10F001 DD UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
C      //DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
C      //GC.SYSIN DD *
C      *****
C      //LAMMO010 JOB (0687,0446FT,CEG9),'L.L.LAMMERS'
C      //EXEC FORTCLG
C      //FCRT.SYSIN DD *
C      *****
C      PROGRAM 10      L.L.LAMMERS      26 JAN 1971
C      READS MASTER TAPE (NPS306) TO DETERMINE TOTAL 80-BYTE RECORDS
C      CONTAINED THEREON

```



```

C      DATA JTOT/0/,NTOT/0/
C      DO 20 I=1,15000
C      READ A TITLE CARD( I COUNTS TOTAL NR OF TITLE CARDS)
C      READ(10,101,END=30) NCARDS
C      IF(NCARDS.EQ.0) GO TO 40
C      READ DATA CARDS (JTOT COUNTS TOTAL NR OF DATA CARDS)
C      DO 10 J=1,NCARDS
C      READ(10,102,END=35) DUMMY
C      FORMAT(A4)
C      CONTINUE
C      JTOT=JTOT+NCARDS
C      CONTINUE
C      WRITE(6,103)
C      FORMAT(//1X,'MORE THAN 15000 TITLE CARDS, STOPPING')
C      STOP
C      GET TO 30 AT END OF TAPE
C      I=1
C      NTOT=I+JTOT
C      WRITE(6,104) I,NTOT
C      FORMAT(//1X,'END OF TAPE(NORMAL): TOT OCEAN STA=',I6,5X,'TOT 80-BY
C      $TIE RECORDS WRITTEN=',I8)
C      STOP
C      WRITE(6,105) I,J
C      FORMAT(//1X,'END OF TAPE(ABNORMAL): I=',I6,5X,'J=',I4)
C      STOP
C      WRITE(6,106) I
C      FORMAT(//1X,'NCARDS=0, STOPPING: I=',I6)
C      STOP
C      END
C      //GC.FT10F001 DD UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
C      //GC.DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
C      //GC.SYSIN DD *
C      *****
C      THE "FINAL COMPUTER PROGRAM" (11) IS LISTED BELOW:
C      *****
C      //LANN011 JOB (0687,0446FT,DEG9),'L.L.LAMMERS'
C      // EXEC FORTCLG,REGION,CC=300K,TIME,GO=10

```







```

39 DO 2000 JMD=1,12
40 WRITE(6,103) JMD
41 DO 1000 I=1,5000
42 READ(10,101) END=175,ERR=980) NCARDS,NMO,LATDEG,RLATMI,LONDEG,
43 $RLONMI,NWFC
44 READ(10,102,ERR=985,END=990) VALT(JV),VALSG(JV)
45 DO 40 JV=1,NCARDS
46 READ(10,102,ERR=985,END=990) VALT(JV),VALSG(JV)
47 CCNT=INUE
48 IF(LT,20) VALUES READ IN,ZEROIZE REMAINDER OF ARRAYS
49 IF(NCARDS+1) GO TO 50
50 NC=NCARDS+1
51 DO 45 JV=NC,20
52 VALT(JV)=0.0
53 VALSG(JV)=0.0
54 CCNT=INUE
55 GET TO 50 WITH ONE STATION READ IN. NOW CHECK FOR CORRECT MONTH
56 IF(NMO,NE-JMD) GO TO 1000
57 IF(NOW FIND BLOCK NR(BLOCKS NOT NUMBERED IN SEQUENCE:SEE BASE CHART)
58 RLAT=100.*LATDEG+RLATMI
59 RLON=100.*LONDEG+RLONMI
60 VERIFY THAT STATION IS IN BAY THEN FIND CORRECT ROW(ROW NRS=55,
61 60,65,70,75,80)
62 IF((RLAT,LT,LE,3633.0).OR.(RLAT,GT,3700.0)) GO TO 1000
63 IF((RLAT,GE,3633.0).AND.(RLAT,LT,3637.0)) GO TO 55
64 IF((RLAT,GE,3637.0).AND.(RLAT,LT,3641.0)) GO TO 60
65 IF((RLAT,GE,3641.0).AND.(RLAT,LT,3645.0)) GO TO 65
66 IF((RLAT,GE,3645.0).AND.(RLAT,LT,3649.0)) GO TO 70
67 IF((RLAT,GE,3649.0).AND.(RLAT,LE,3653.0)) GO TO 75
68 IF((RLAT,GT,3653.0).AND.(RLAT,LE,3700.0)) GO TO 80
69 SELECT COLUMN WITHIN ROW. K DEFINES BLOCK NRE(SEE BASE CHART)
70 IF(RLON,GT,12208.0) GO TO 1000
71 IF(RLON,LT,12203.0) K=15
72 IF(RLON,GE,12203.0) K=12
73 GO TO 85
74 IF(RLON,LT,12153.0) GO TO 1000
75 IF(RLON,GT,12230.0) GO TO 1000
76 IF((RLON,GE,12208.0).AND.(RLON,LT,12223.0)) GO TO 1000
77 IF((RLON,GE,12153.0).AND.(RLON,LT,12158.0)) K=14
78 IF((RLON,GE,12158.0).AND.(RLON,LT,12203.0)) K=11
79 IF((RLON,GE,12203.0).AND.(RLON,LE,12230.0)) K=20
80 IF(RLON,LT,12153.0) GO TO 1000
81 IF(RLON,GT,12223.0) GO TO 1000
82 IF((RLON,GT,12208.0).AND.(RLON,LT,12213.0)) GO TO 1000

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IF((RCON.GE.12203.0).AND.(RCON.LE.12208.0)) K=10
IF((RCON.GE.12213.0).AND.(RCON.LE.12218.0)) K=23
IF((RCON.GE.12218.0).AND.(RCON.LE.12223.0)) K=21
GO TO 85
70 IF(RCON.GT.12208.0) GO TO 100
IF(RCON.LT.12153.0) K=19
IF((RCON.GE.12153.0).AND.(RCON.LT.12158.0)) K=17
IF((RCON.GE.12158.0).AND.(RCON.LT.12203.0)) K=3
IF((RCON.GE.12203.0).AND.(RCON.LE.12208.0)) K=9
GO TO 85
75 IF(RCON.GT.12208.0) GO TO 100
IF(RCON.LT.12153.0) K=18
IF((RCON.GE.12153.0).AND.(RCON.LT.12158.0)) K=6
IF((RCON.GE.12158.0).AND.(RCON.LT.12203.0)) K=4
IF((RCON.GE.12203.0).AND.(RCON.LE.12208.0)) K=8
GO TO 85
80 IF(RCON.GT.12218.0) GO TO 100
IF(RCON.LT.12158.0) K=16
IF((RCON.GE.12158.0).AND.(RCON.LT.12203.0)) K=5
IF((RCON.GE.12203.0).AND.(RCON.LT.12208.0)) K=7
IF((RCON.GE.12208.0).AND.(RCON.LT.12213.0)) K=24
IF((RCON.GE.12213.0).AND.(RCON.LE.12218.0)) K=22
IF GET TO 85 WITH ONE VALUE OF K(BLOCK NR). LCAD 3-D ARRAYS.
IF(NWF.EQ.9) GO TO 150
IF(LCAD.UNWEIGHTED TEMPS
NR(K)=NR(K)+1
NRK=NR(K)
C COUNTS TOTAL UNWEIGHTED TEMPS IN GIVEN BLOCK
IF(VALSG(1).EQ.0.0) GO TO 90
C GET HERE IF THERE IS UNWEIGHTED(U.W.) SIGMA-T DATA. NS(K) COUNTS
TOT U.W. SIGMA-T STATIONS IN BLOCK
NS(K)=NS(K)+1
NSK=NS(K)
DO 95 J=1,20
TEM(J,K,NRK)=VALT(J)
IF(VALSG(1).EQ.0.0) GO TO 95
SGT(J,K,NSK)=VALSG(J)
CONTINUE
C NOW GET ANOTHER STATION
GO TO 100
C GET TO 150 TO LOAD WEIGHTED DATA INTO 3-D ARRAYS.
150 MR(K)=MR(K)+1
MRK=MR(K)
C COUNTS TOT WEIGHTED TEMPS & SIGMA-T'S FOR BLOCK
DO 160 J=1,20

```



```

119 TEMW(J,K,MRK)=VALT(J)
120 SGTW(J,K,MRK)=VALSG(J)
121 CONTINUE
122 GET ANOTHER STATION
123 GO TO 1000
124 GET TO 175 AFTER ALL DATA READ IN. COMMENCE PROCESSING
125 I=I-1
126 REWIND IC 104) I
127 WRITE(6,104) I
128 DC 300 K=1,24
129 IF NO WEIGHTED DATA(MR(K)=0),CHECK U.W. DATA(NR(K)) AND IF NONE,
130 SKIP KTH BLOCK
131 IF((MR(K).EQ.0).AND.(NR(K).EQ.0)) GO TO 300
132 WRITE(6,105) K
133 DO 295 J=1,20
134 DETERMINE TYPE DATA. MR(K) COUNTS WEIGHTED TEMPS & SIGMA-T'S,
135 NR(K) COUNTS UNWTD SIGMA/T'S
136 IF(MR(K).EQ.0) GO TO 185
137 MR=NR(K)
138 CLEAR ZERO VALUED WTD TEMPS & SIGMA/T'S FROM ARRAY
139 DO 180 L=1,MRT
140 IF(TEMW(J,K,L).EQ.0.0) GO TO 180
141 MMW=MMW+1
142 MMW COUNTS TOT NON-ZERO WEIGHTED TEMPS(OR SIGMA-T'S)
143 TEMW(J,K,MMW)=TEMW(J,K,L)
144 SGTW(J,K,MMW)=SGTW(J,K,L)
145 ACCUMULATE WEIGHTED SUMS
146 SUMTW=SUMTW+TEMW(J,K,MMW)
147 SUMSTW=SUMSTW+SGTW(J,K,MMW)
148 TWSQ=TWSQ+TEMW(J,K,MMW)**2
149 STWSQ=STWSQ+SGTW(J,K,MMW)**2
150 CONTINUE
151 COMPUTE STANDARD DEVIATION FOR WEIGHTED TEMPS AND SIGMA-T'S,
152 USE GENERAL EQUATION:
153 S=SQRT((XSUBI**2-N*XBAR**2)/(N-1)), WHERE:
154 S=STDEV(SDSTW) XSUBI**2=TWSQ,STWSQ
155 N=MMW XBAR**2=TWAV,STWAV
156 IF MMW.LE.1, SKIP STANDARD DEVIATION ALTOGETHER
157 IF(MMW.LE.1) GO TO 185
158 TWAV=(SUMTW/FLCOT(MMW))**2
159 STWAV=(SUMSTW/FLCOT(MMW))**2
160 T1=(TWSQ-MW*TWAV)/FLCOT(MMW-1)
161 SDTW=SQRT(T1)
162 ST1=(STWSQ-MMW*STWAV)/FLCOT(MMW-1)
163 SDSTW=SQRT(ST1)
164 GET TO 185 TO PROCESS UNWEIGHTED DATA. FIRST SEE IF THERE IS ANY.
165 IF(NR(K).EQ.0) GO TO 205

```



```

150 DO 190 L=1,NRT
151 IF (TEM(J,K,L).EQ.0.0) GO TO 190
152 MT=MT+1
153 C NT COUNTS NON-ZERO U.W. TEMPS
154 TEM(J,K,MT)=TEM(J,K,L)
155 ACCUMULATE SUMS
156 SUMT=SUMT+TEM(J,K,MT)
157 TSQ=TSQ+TEM(J,K,MT)**2
158 C CONTINUE
159 C COMPUTE STDEV FOR U.W. TEMPS AS BEFORE
160 IF (MT.LE.1) GO TO 205
161 TUWAV=(SUMT/FLOAT(MT))**2
162 T2=((TSQ-MT*UWAV)/FLOAT(MT-1))
163 SDTUW=SQRT(T2)
164 NCW PROCESS U.W. SIGMA-T'S
165 IF (NS(K).EQ.0) GO TO 205
166 NST=NS(K)
167 C CLEAR ZERO U.W. SIGMA-T VALUES FROM ARRAY
168 DO 200 L=1,NST
169 IF (SGT(J,K,L).EQ.0.0) GO TO 200
170 MST=MST+1
171 C MST COUNTS NON-ZERO U.W. SIGMA-T'S
172 SGT(J,K,MST)=SGT(J,K,L)
173 ACCUMULATE SUMS
174 SUMST=SUMST+SGT(J,K,MST)
175 TSQ=TSQ+SGT(J,K,MST)**2
176 C CONTINUE
177 C COMPUTE STDEV OF U.W. SIGMA-T'S AS BEFORE
178 IF (MST.LE.1) GO TO 205
179 STUWAV=((SUMST/FLOAT(MST))**2
180 ST2=((TSQ-MST*STUWAV)/FLOAT(MST-1))
181 SDSTUW=SQRT(ST2)
182 GET TO 205 TO PROCESS COMBINED(WTD & U.W.) AVGS AND SUMS
183 IF ((MMW.EQ.0).AND.((MT.EQ.0)) GO TO 290
184 GET HERE IF EITHER, CR BOTH WTD AND UNWTD DATA
185 A1=MT+4.0*MMW
186 TSUMT=SUMT+4.0*SUMTW
187 TAVT=TSUMT/A1
188 IF ((MST.EQ.0).AND.((MMW.EQ.0)) GO TO 220
189 A2=MST+4.0*MMW
190 TSUMST=SUMST+4.0*SUMSTW
191 TAVST=TSUMST/A2
192 NCW WRITE RESULTS, HEADING FIRST
193 WRITE(6,106)
194 WRITE(6,107)

```



	WRITE(6,108) STDEP(J),TAVT,TAVST,MMW,SUMTW,SDTW,SUMSTW,SDSTW,MT,	184
	\$SUMT,SDTUM,MST,SUMST,ZERO	185
	LIST ALL NCN-ZERO VALUES	
	IF(MMW.EQ.0) GO TO 225	186
	WRITE(6,109) (TEMW(J,K,L),L=1,MMW)	187
	WRITE(6,110) (SGTW(J,K,L),L=1,MMW)	188
	IF(MT.EQ.0) GO TO 290	189
225	WRITE(6,111) (TEM(J,K,L),L=1,MT)	190
	IF(MST.EQ.0) GO TO 290	191
	WRITE(6,112) (SGT(J,K,L),L=1,MST)	192
	NOW SET ALL COUNTERS TO ZERO AND PROCESS FOR NEXT STD DEPTH	
C 290	MMW=0	193
	SUMTW=0.0	194
	SUMSTW=0.0	195
	TWSQ=0.0	196
	STWSQ=0.0	197
	TAWAV=0.0	198
	STWAV=0.0	199
	T1=0.0	200
	SDTW=0.0	201
	ST1=0.0	202
	SDSTW=0.0	203
	MT=0	204
	SUMT=0.0	205
	TSQ=0.0	206
	TUWAV=0.0	207
	T2=0.0	208
	SDTUM=0.0	209
	MST=0	210
	SUMST=0.0	211
	STSQ=0.0	212
	STUWAV=0.0	213
	ST2=0.0	214
	SDSTUM=0.0	215
	A1=0.0	215A
	TSUMT=0.0	215B
	TAVT=0.0	215C
	A2=0.0	215D
	TSUMST=0.0	215E
295	CONTINUE	216
300	GO TO 1500	217
980	WRITE(6,113) I	218
985	STOP	219
990	WRITE(6,114) I,JV	220
	STOP	221
	I=I-1	222
		223





```

227 WRITE(6,116)
228 STOP
229 C ZEROIZE ALL ARRAYS AND START OVER AGAIN WITH NEXT MONTH
230 DC 1550 J=1,24
231 NR(J)=0
232 NS(J)=0
233 MR(J)=0
234 CONTINUE
235 DO 1600 JJ=1,20
236 DO 1590 KK=1,24
237 DO 1560 LL=1,60
238 TEM(JJ,KK,LL)=0.0
239 CONTINUE
240 DO 1570 LM=1,30
241 SGT(JJ,KK,LM)=0.0
242 CONTINUE
243 DO 1700 JW=1,20
244 DO 1690 KW=1,6
245 DO 1680 LW=1,20
246 TEMW(JW,KW,LW)=0.0
247 SGTW(JW,KW,LW)=0.0
248 CONTINUE
249 DO 1680 CONTINUE
250 DO 1700 CONTINUE
251 DO 1690 CONTINUE
252 WRITE(6,117)
253 STOP
254 END
255 //CC.FT06F001 DD SPACE=(CYL,(3,1))
//GC.FT10F001 DD UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//GC.DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GC.SYSIN DD *
C
C ***** END OF PROGRAMS *****

```



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### Mean Monthly Thermal Conditions







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